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THE PHYSICS OF FLIGHT.*

BY

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INTRODUCTION.

THERE have been many publications in the last few years on the application of physics to the design and construction of airplanes and to the theory of their stability, and much progress has been made on these intricate and important questions. But for every one man who designs a successful airplane there are many who must fly it, and the application of physics to the problems of actual flight has been comparatively neglected, so much so, in fact, that many pilots even overlook entirely the value of physics to a flyer. In this they are apparently confirmed by the fact—and it is a fact—that most of our best pilots during the war were ex-cavalry officers and other men whose previous experience had been such as to cultivate almost any form of knowledge but that of physics. Notwithstanding this, an airplane is governed by the laws of physics, and unless these laws can be made to help a pilot there is some important defect in our system of the teaching of physics. The question is whether this defect is in the laws covered in our physics courses, or the methods of using these laws, or both.

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This question was of especial interest to me in learning the art of flying, because I had been teaching physics for some years, and had been much dissatisfied with the conventional methods of teaching and their results, and had often noticed the same apparent futility of the text-book style of physics in sailing a boat, repairing an automobile, and other applications of the laws of physics where arithmetic does not enter. Such cases suggested strongly that the inadequacy of physics as taught was not so much in the laws as in the methods. The purpose of the present article is not to present any new laws of aerodynamics, and no effort will be made to trace each law to its discoverer, but it is rather to show what appears to me, as a pilot and a physics teacher, to be the best way of presenting the subject to men who are going to fly.

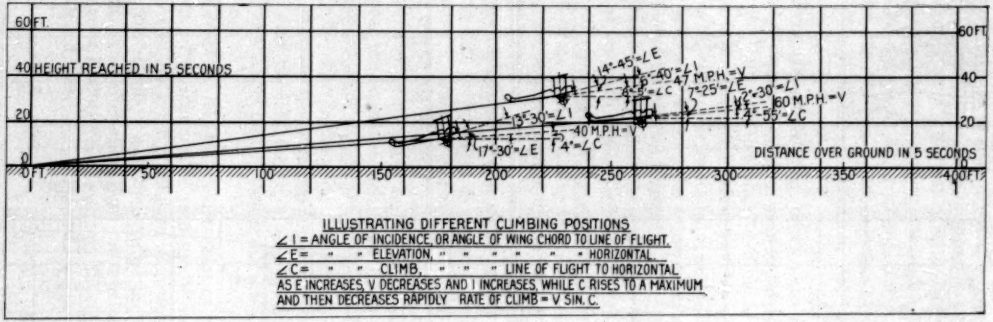
WHAT IS THE PHYSICS OF FLIGHT?

To see what sort of physics a flyer does need, let us examine briefly some typical problems arising in actual flying. We can then examine the laws underlying them, put these laws in the most suitable form, and apply them to some of the problems.

First, let us take the problem of how to climb to 10,000 feet, or some other given altitude, in the quickest time. The first requirement is of course full throttle. Then comes the question of how steeply to elevate the nose of the airplane. If the nose is held too level, the machine will make a high speed, but on a nearly level course. If it is held somewhat steeper the course will be steeper, but the speed lower, and if the speed is too much reduced in this way it may more than neutralize the effect of the steeper course. And if the nose is held too steep, the course, as a matter of fact, may even become more level again, as illustrated in Fig. 1. The first question is how to tell what angle of elevation is best, and the second is whether, in practice, to identify this angle by a spirit level, the horizon, the air speed meter, the " feel of the ship," or something else.

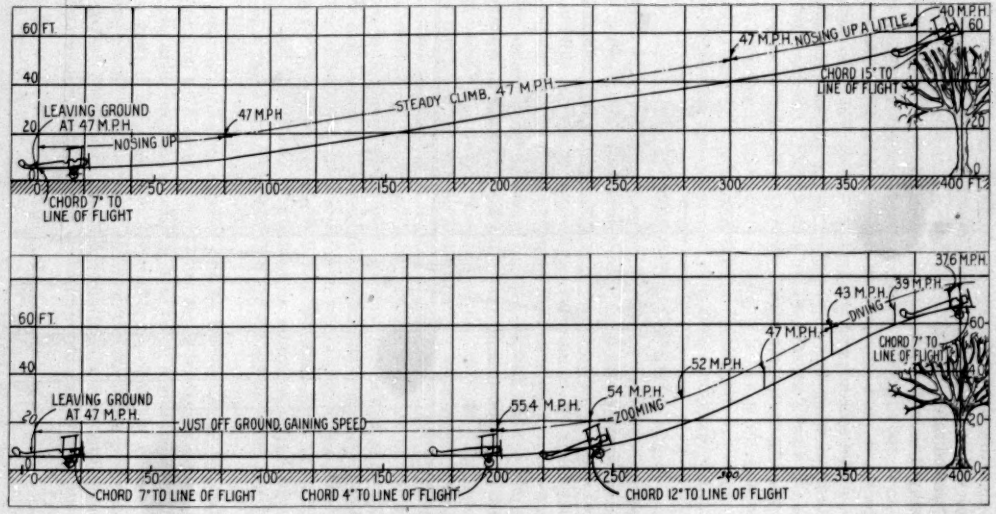
A second problem, closely related to the above, is that of climbing out of a small field where there is danger of striking some obstacle, such as a telegraph wire or a row of trees. In such a case it is sometimes impossible to clear the obstacle by climbing at the ordinary best angle of elevation but just possible to do so by " zooming "; that is, by holding the nose level, heading for the obstacle, perhaps ten or twenty feet below the top, and

FIG. 1.



ILLUSTRATING DIFFERENT CLIMBING POSITIONS
∠I = ANGLE OF INCIDENCE, OR ANGLE OF WING CHORD TO LINE OF FLIGHT.
∠E = " " ELEVATION, " " " " " " HORIZONTAL.
∠C = " " CLIMB, " " " " LINE OF FLIGHT TO HORIZONTAL.
AS E INCREASES, V DECREASES AND I INCREASES, WHILE C RISES TO A MAXIMUM AND THEN DECREASES RAPIDLY. RATE OF CLIMB = V SIN. C.

FIG. 2.



Illustrating a zoom that pays with a ship of fairly high power.

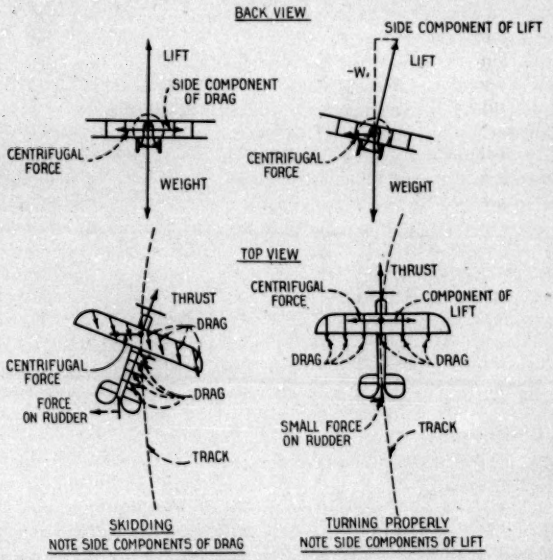
then elevating the nose so as to rise very steeply over the obstacle, then levelling out and perhaps dropping below it on the other side, as indicated in Fig. 2. Several questions arise here, such as: why does this trick work; does it always pay; if it works, why is it not a good way to begin a long climb; is there any danger in it; and why do you fly level in the first part of the process, at a sacrifice of altitude, rather than climb as long as you can and then zoom?

A third problem, also on climbing, arises when you climb out of a field against a strong wind and wish to turn to go before the wind. If you "turn off the wind" within a few hundred feet of the ground, the airplane is often very unsteady laterally during the turn, and sometimes banks up so suddenly as to side-slip toward the ground. This is the cause of many accidents, and such turns should be avoided if possible. An explanation of this effect, accepted by many pilots, is as follows: "If you climb at an air speed of 60 m.p.h. against a wind of 15, your ground speed is 45. If now you turn off the wind your air speed drops from 45 *plus* 15, to 45 *minus* 15, and you drop with it." Now this explanation is not only contrary to the most fundamental principles of mechanics, but has the additional disadvantage that it leads to wrong conclusions. From it one would infer that if you could make a turn safely once, in a given wind, you would be safe in repeating it, whereas you are not. And from it one would infer that if you see whether you get any instability in a given turn at two or three thousand feet altitude, you will know what to expect near the ground, which again is not true, because this instability fails to occur except near the ground. The question is, What is the true explanation and how will you avoid this danger? And as one phase of this question, can you avoid it by "skidding" your turn, as shown in Fig. 3, the way many pilots do in such cases, and if you try this, is there any other danger caused by skidding?

As a fourth problem, let us consider some of the questions arising in landing. For example, if your motor stops and it is doubtful whether you can reach a field you want to land in, how shall you tell at what angle to hold the nose of the ship to make the flattest glide? And what effect does the wind have on your answer? Or if your landing field is almost directly below you, why can you descend faster in a "spiral" (or more exactly, a

helix) than you can in a series of long steep glides, without getting an excessive air speed? Or if the line to your field is steeper than you care to glide, why can you shorten your glide by turning the nose from side to side with the rudder, the wings being level, and making a series of short "skids"? And is there any danger in this process? Or, why, under such circumstances,

FIG. 3.



Illustrating forces in a skidding turn.

can you get the same result by banking the ship, without allowing it to turn, and sideslipping steadily toward the field? Is there any danger in this? And why is sideslipping preferable to skidding? And is it better to come out of the sideslip by using the rudder or the ailerons? And if great accuracy is required in the length of your glide, is it safe to continue a sideslip till you are very near the ground? And if you approach the ground at a low

speed in an ordinary glide and try to level off for a landing, why does the ship refuse to change its course as fast as you change the elevation of the nose, and settle below the course you steer for, often landing with something of a shock unless you allow for this effect?

A fifth type of problems is that of the effects of gusts—"bumps," "holes in the air," etc.—both in the motions of the machine and in the strains introduced by them.

A sixth type of problem is connected with stability and includes such questions as these: At what speeds is a ship most likely to be longitudinally unstable, and does every ship insist on diving if the speed is reduced to the "stalling speed"? And how is the longitudinal stability and the action on stalling affected by changes in the position of the load? Why does the ship tend to roll easily at low speeds and especially on stalling, and why do the ailerons lose their effect at slow speeds and actually reverse it at a speed just above the stalling point? And why, in making a turn at the proper angle of bank, does the ship tend to increase its bank and have to be held from doing so by the ailerons? Is this ever a source of danger? And in rough air do you lose more speed by allowing the ship to get off its course and bringing it back at your leisure or by constantly watching for bumps and correcting them quickly? And what is the relation of the mathematical theory of stability to practical flying?

Finally, we have the questions of acrobatics. What are the various "stunts" and why do certain motions of the controls produce the effects they do? Why should all controls be moved slowly and easily, and to which ones does this rule apply most strongly?

Now these questions are all highly practical problems on the application of the laws of physics, and every good pilot must answer all of them, and many more, except perhaps those beginning with "why." Three important general questions are, therefore: how can he answer them without knowing physics; what is the value of the questions beginning with "why"; and what is lacking in our text-book physics that makes it of little value in the art of flying?

The answer to the first of these questions is this—by long practice and observation. Hence the great stress laid by pilots on the number of "hours in the air" that a man has had. There are so

many of these questions and they are all so varied by minor factors, that if they must all be answered by this empirical method, very many hours are indeed necessary. But with the cost in the neighborhood of a dollar per minute, this is not the ideal method of study. Nor is it free from danger, though it must be remembered that flying is far from the dangerous occupation it once was, even to a novice. However, anything that lengthens the period when a man is uncertain as to what will happen or what to do next is unpleasant. This uncertainty can be avoided to some extent by acquiring a rather artificial self-confidence and habit of forming very positive opinions, and the result is positive action in any case, which is much better than any hesitancy even if it is not the best action. But even this procedure has the disadvantage of making a man feel like the "King of the Air," as one pilot expressed it to me. The "divine right of kings" is not so popular as it once was, and abdications are usually sudden.

These facts answer also the second question, on the value of the "whys." The difference between empiricism and science is the existence of "whys" in science, and these scientific connections between facts are just what we need to avoid the troubles just mentioned.

Now as to the third question, the trouble with the text-book physics. On the problem of climbing to 10,000 feet, outlined first in the above collection, the text-book methods are fairly good and the principles are all there. We have merely to calculate the power available at any given air speed and the power required by resistance and subtract to get the power used against gravity. This can be done on the ground, if the data are available, and the best air speed can be determined. Or, more exactly, it can be figured approximately and we can make sure that the same air-speed will be best under the same conditions in different flights, and use a value determined by experiment. As to what instrument to use for identifying this speed, we can show that the air speedmeter is best because its reading is almost the same for the best climbing rate under many different conditions, while that of the spirit level is not so. This problem, then, is one that can be fairly well solved by the text-book methods. The problems of navigation likewise come in this class and on such problems the navigating instruments including the airspeedmeter, are invaluable aids. This makes these instruments, in fact, almost as

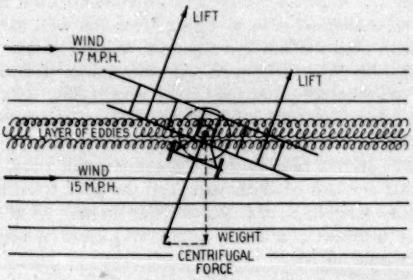
important as the tachometer, oil gauge and thermometer on which the pilot depends for a knowledge of the conditions of his motor. But these are not all the problems of flying.

When we come to the zooming problem, the case is different. Conditions are more complex, and there are not only more major factors in the problem, such as the distance across the field, the height of the obstacle, the speeds of the machine and the wind, the rates of climb at different speeds, the forces introduced by the accelerations in the zoom, and others, but there are also many minor factors, such as small unexpected irregularities of the ground the machine runs on, gusts of wind, etc. And above all, there is no time to figure anything, and the pilot must have his eyes outside the ship and not on any instruments, and therefore can have no numerical data to figure from, as well as no time to figure with even the simplest formula, and no simple formula that can possibly take account of even the major factors. The neat little quantitative problems of the text-books, with exactly three data when the formula calls for three, and the formula only two pages back, are poor training indeed for the application of physics to such a case as this. But the result must be none the less exact for lack of arithmetic, and the pilot must know by intuitive reasoning in a few seconds the answer of a problem insoluble by arithmetic in a few hours, and know it better than arithmetic would tell him.

In all the other problems stated above the case is the same, and one of them, especially, brings out another point. If we apply the text-book methods to the problem of turning off the wind, we would say that the principle of relative motion would settle it at once, and that there was no reason at all why a turn off the wind should make the machine act differently from one turning into the wind at the same air speed, the ground speeds only being different. But the fact is that the difference, if you are near the ground, is large and important, and this difference is due to what seems like a minor factor. Namely, the wind is likely to form rather sharply defined layers, of different speeds, the higher ones moving faster. This effect has been known to sailors for centuries. In this case, if the machine is banked in the turn and strikes the boundary of two such layers, it may easily be tipped over by the difference of speed of the wind on the wings, as shown in Fig. 4. This explanation, which was sug-

gested to me by Dr. W. J. Humphreys, accounts perfectly for the observed facts. The question of the advisability of skidding this turn will be discussed below. The point of importance here is the grave danger of following the usual text-book procedure, of cutting off all the minor factors of the problem, perhaps without even mentioning them, solving a much simplified numerical problem, and then completely forgetting to make any attempt to find how the minor factors would modify the result. It has become so customary to consider a quantitative answer as the sure indication of rigorous thinking, that we sometimes forget that correct qualitative work is much more rigorous than incor-

FIG. 4.



Illustrating forces introduced by striking different wind layers in turning off the wind.

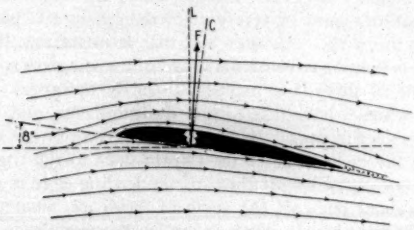
rect quantitative, and that figures can lie, in spite of the proverb, if we lie to them first about the data. Even if truth were not the *raison d'etre* of rigor, it would still be better than a mere appearance of a rigor that is not there.

In the physics of flight, then, we must formulate our laws in such a way that they can be used quickly and accurately, with not much regard for the possibility of numerical work, and if possible we must reduce them to a basis either of familiar fundamental laws of mechanics or of something the pilot can quickly verify for himself. And above all they must be such as to allow the introduction of minor factors and they must replace the quantitative element that appears in engineering as arithmetic by a fine sense of proportion and a clear, rigorously correct, though non-arithmetical, analysis of the problems.

FUNDAMENTAL PRINCIPLES.

The supporting forces and resistance of the wings depend on the flow of air past them, and if the character of this flow is understood it should be easy for the pilot to understand the behavior of the machine. Now the character of the flow is itself easy to observe, by simply tying small bits of tape to various parts of the wires. One may observe the directions of flow from the way the tapes stand out in the wind, and thus form an idea of the stream lines. And one may see differences in the speed of the air at different points by the speed of fluttering of the tapes. If tapes on the wires do not satisfy one's curiosity, the observations may be extended by rigging sticks in other places with tapes on the ends of long nails stuck in them.

FIG. 5.



The results of such observations depend greatly on the angle of incidence, or angle of attack, which is the angle between the wing chord and the line of flight, but they are of course independent of the angle of either line to the horizontal.

For a moderate angle of attack, such as we would use in climbing, the stream lines around a good wing are approximately like those shown in Fig. 5. If we define a normal speed to be that at a long distance away from the wing, we find a higher speed just above the forward part of the wing and a lower speed just below it, while conditions are more normal, or perhaps slightly reversed, near the trailing edge. This is as we might expect, since the stream lines over the top of the wing must diverge to fill the space over the trailing edge, and those below the leading edge must converge. Now we may estimate the pressures involved in either of two ways. One, less familiar and less con-

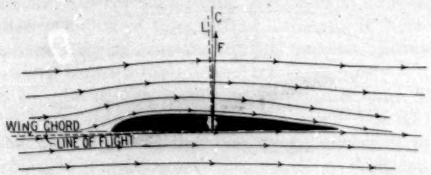
vincing to the novice, is by Bernoulli's theorem, that makes the pressure low wherever the speed is high in a stream line not exposed to friction. This means suction on top and pressure below, both especially strong on the forward part of the wing. A more convincing method is to consider the centrifugal effect due to the curvature of the stream lines, which obviously involves a strong suction on the strongly curved part of the upper surface, and a fairly good pressure on the forward part of the lower one. This looks at first like a different effect from Bernoulli's, and as though we should add the two, but a closer examination would show that Bernoulli's principle, in the restricted form given above, refers to the difference in pressure at points *along* a stream line, while the centrifugal analysis refers to a difference *across* the stream lines, so that these differences are not in such positions as to be added. By either method alone, we may compute the pressure at any point by reference to the pressure at points very far from the wing. Another fact that is important, illustrated in Fig. 5, is that the stream lines ahead of the wing are not parallel to the line of flight, but inclined distinctly upward. This is a point on which I have taken exact measurements, and it is confirmed by experiments of other observers. According to my measurements the inclination of the stream lines to the true line of flight, at one chord length ahead of the leading edge in a Curtiss JN4H is about one-half the angle of incidence, whatever value that angle may have. That is, an incidence indicator at this point always reads about 50 per cent. too high. The explanation is probably that the downward motion of the air behind the wing forces an upward motion ahead and on the sides. The importance of it to us is that it increases the curvature of the lines and the resulting centrifugal effects.

Another important point is that since the centrifugal effect is strongest on the strongly curved part of the upper wing, it is important to have most of this curvature occur in a region where the normal to the surface is inclined forward of the normal to the wing chord, as it is in the forward part of the surface. Since the suction is normal to the surface, this makes the strongest suction on the wing have a distinct forward component, thus balancing much of the backward force offered by other parts. This accounts for the superiority of wings that are thickest at a point well forward of the centre, and also for the fact that the

resultant force is inclined forward of the normal to the chord as shown in Fig. 5, although, of course, it is back of the normal to the line of flight. It is most important to have the resultant force inclined backward as little as possible because it is the component of this force backward along the line of flight that makes us need a motor, and we may congratulate ourselves that in spite of the yielding nature of the air this component may be made not much larger than if the machine were sliding on a greased metal surface. The component upward, perpendicular to the line of flight, will be referred to hereafter as the "lift" and the component backward, along the line of flight, as the "drag."

As the angle of incidence is *reduced* the action of the lower surface is obviously weakened, and the space to be filled by the stream over the upper surface is reduced, as shown in Fig. 6. At

FIG. 6.

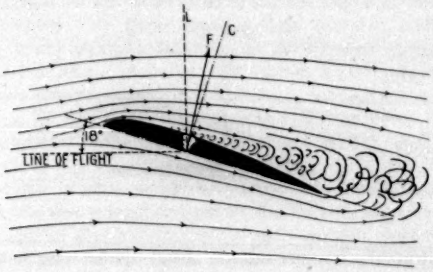


the same time the upward motion ahead of the wing is reduced, and a downward pressure appears on a narrow region near the leading edge, where the air is deflected upward by it. The result of all this is to weaken the lift and to a less extent the drag, at any given speed, and also to shift the centre of pressure back along the wing. Now the weakened lift at a given speed means that small angles of attack can be used only at high speeds, and the shift of the centre of pressure is such as to make a machine whose speed is increased tend to dive and increase it more. This shift of the centre of pressure produces a tendency to longitudinal instability, that must be corrected by other features in the design.

On *increasing* the angle of incidence above a moderate amount, the effects are at first practically the reverse of those found in reducing it, though the drag soon begins to increase faster than the lift and the centre of pressure becomes almost stationary. But at a certain angle the space above the back of the wing be-

comes too large to be filled by the stream lines over the top without causing a suction so great as to draw air in from other regions, especially from the crowded stream lines just below the trailing edge. If this angle is approached gradually by slowing the machine, and you have a piece of tape on a wire near the surface of the wing at the foot of one of the rear struts, you can see this tape cease its rapid fluttering, settle for an instant on the surface of the wing, and then tie itself up in a tangle, showing the formation of a mass of eddies. Just as this happens, the wing loses its lift and the machine starts to fall. At the same time it dives, showing that the centre of pressure has shifted aft, and the loss of lift was mainly on the forward part of the wing,

FIG. 7.



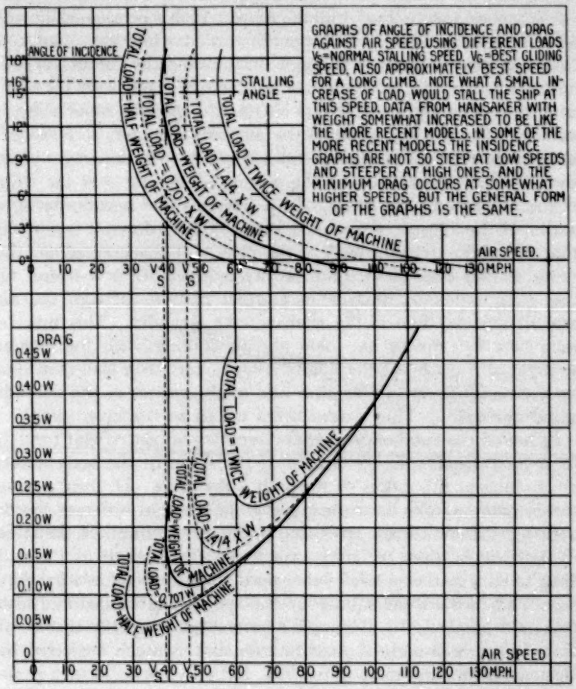
where the tapes are still fluttering as before. The explanation is simple. The stream lines over the top of the wing no longer have to fill all the space over the back, and have lost some of their speed and much of their curvature, as shown in Fig. 7, and much of their centrifugal effect is lost. Incidentally as the forces on the wing due to these stream lines had a forward component as well as an upward one, their loss means an increase of drag as well as a decrease of lift. This behavior of the wing is called stalling, and occurs at a definite angle for any given form of wing. For the forms in common use the stalling angles are between 13 and 16 degrees. On increasing the angle of incidence beyond the stalling angle, the mass of eddies gets thicker, the lift decreases more, while the drag increases. These changes may be followed easily by watching the tapes on the wires.

The most noticeable fact about the motion of an airplane just before it stalls is the lateral instability that serves as a warning of the stall. This lateral instability increases during the stalling process because, if either wing stalls before the other, it drops down and holds back at the same time, thus increasing its angle of incidence and stalling it all the more. If this process is allowed to continue, that wing will remain stalled while the other one keeps its normal motion through the air, and the result is a tail-spin. In fact, the tail-spin may be distinguished from the spinning nose-dive by the fact that in the tail-spin the inner wing is stalled, although the speed of the machine increases to considerably more than the ordinary stalling speed. An important point that is explained readily by the motion of the air over the wing is the reversal of the action of the ailerons that occurs during a stall. If the aileron of a stalled wing is tipped down it is obvious that the eddies over the back of the wing will be increased and the wing stalled even more than before, whereas if it is tipped up the wing tends to recover its normal motion through the air and lifts more than if the aileron were straight. This may be seen best by gliding the ship almost stalling with the rudder straight and throwing the ailerons hard over. She will then spin in a direction opposite to that one might expect if the ailerons acted normally. This is sometimes called an "aileron spin."

One of the fundamental characteristics of centrifugal force is its proportionality to the square of the speed of the body it acts on, so long as the radius of the path is the same. If, then, a wing can be made to take the same angle of incidence at different speeds by using different loads on it, and if the stream lines are the same in both cases, then we may expect the forces both of lift and drag to vary as the square of the speed. This, in fact, is what they do. This law of the square of the speed may be deduced also from the analysis by Bernoulli's principle, or by the theory of dimensions, a branch of mathematics that is much neglected by most engineers and many physicists, but very useful in such problems as this. By any of these methods we may likewise show that the law will hold only if the shapes of the stream lines are independent of the speed. Because it does hold, any reasonable angle of incidence can be used in steady flight with any load, provided the speed is properly adjusted, and at any given angle of incidence the ratio of lift to drag has a definite value, and hence

the drag at a given speed is calculable from the load. We may therefore plot a series of graphs of incidence and wing drag against air speed for different loads. As the resistance of other

FIG. 8.


GRAPHS OF ANGLE OF INCIDENCE AND DRAG AGAINST AIR SPEED, USING DIFFERENT LOADS
V_S = NORMAL STALLING SPEED. V_G = BEST GLIDING SPEED, ALSO APPROXIMATELY BEST SPEED FOR A LONG CLIMB. NOTE WHAT A SMALL INCREASE OF LOAD WOULD STALL THE SHIP AT THIS SPEED. DATA FROM HANSAKER WITH WEIGHT SOMEWHAT INCREASED TO BE LIKE THE MORE RECENT MODELS. IN SOME OF THE MORE RECENT MODELS THE INSIDENCE GRAPHS ARE NOT SO STEEP AT LOW SPEEDS AND STEEPER AT HIGH ONES, AND THE MINIMUM DRAG OCCURS AT SOMEWHAT HIGHER SPEEDS, BUT THE GENERAL FORM OF THE GRAPHS IS THE SAME.
ANGLE OF INCIDENCE
STALLING ANGLE
TOTAL LOAD = HALF WEIGHT OF MACHINE
TOTAL LOAD = 0.707 X W. WEIGHT OF MACHINE
TOTAL LOAD = 1.414 X W. WEIGHT OF MACHINE
TOTAL LOAD = TWICE WEIGHT OF MACHINE
AIR SPEED.
DRAG
AIR SPEED

parts of the machine, the "parasite resistance," at a given angle of incidence, is also proportional to the square of the speed, we may add it to the wing drag, and plot the total drag against the load at different speeds. The form of the resulting graphs may be predicted qualitatively from the above theory, but for

definiteness we shall use some quantitative data, shown in Fig. 8. These are calculated from some data on a model taken by Hunsaker in the wind tunnel at the Massachusetts Institute of Technology and published in the Smithsonian Miscellaneous Collections, vol. 62, Nov. 5, 1916.

SOLUTIONS OF CLIMBING AND LANDING PROBLEMS.

We are now in a position to solve at once many of our climbing and landing problems. Take first the problem of a slow landing, where the observed fact is that if you level out for a landing from a slow glide, your machine settles distinctly below the direction you steer it for, and may land with a shock unless you allow for this settling. As a slow landing is required in any very small field, it is of some importance to understand the nature of this phenomenon. If you glide slowly, you are using a large angle of incidence, perhaps not far from the stalling angle. Now if you try to level out, you introduce an upward acceleration, and (using d'Alembert's principle) a downward centrifugal force, thus putting an extra load on your wings. This, according to Fig. 8, requires a change of angle of incidence to a higher value, and hence results in a motion of the machine in a direction below that which you would expect it to take if you were not looking for such a change. In fact, if you try to level off too quickly from a glide too slow, your machine may even stall at a speed above the normal stalling speed and settle much quicker than you expect, hence landing with a shock. This makes it somewhat unstable laterally, as is always the case in a stall, and is liable to make you break a wing-skid.

Another problem involving an angle of incidence increased by a centrifugal load, is that of the "spiral" glide. In such a glide, a steep descent may be made without excessive speed. Here the load is the resultant of gravity and a centrifugal force not vertical, but the load is greater than if gravity alone were acting. Hence, by Fig. 8, the drag is greater. It is this increased drag that prevents a high speed on the steep spiral descent.

A more difficult problem is that of zooming over a telegraph wire. The effect observed is that if you climb at the normal best climbing position until the last moment and then zoom, you can not gain more than a very few feet in the zoom, whereas if you fly more level first, at a sacrifice of initial altitude, you can some-

times clear a point perhaps ten feet higher than by the first method. Either way is far from safe, and the method of zooming is not always the best, and if it is done at all, the nature of the trick should be understood. First, if you climb steadily at the best speed, you pick the speed where the difference between the power available and the power required is a maximum. At this speed your angle of incidence is about 6 to 8 degrees in most machines. Now suppose you zoom. You introduce an upward acceleration, a downward centrifugal force, and the result is much like that of the problem of levelling out from a slow glide. Any attempt to zoom high under these conditions is sure to result in a stall. But if you fly more level at first, and gain a higher speed, your wings can lift a heavier temporary load of centrifugal force and you can zoom higher. Moreover, when you clear the telegraph wire you can be making a downward curve, thus lightening your wing load by an upward centrifugal force, and you can go at a speed distinctly lower than the normal stalling speed without stalling. The height you can attain is determined by the total energy available from your motor in the flight minus the loss due to the drag and minus the kinetic energy at the top of the curve. Hence the best results are obtained if you do not fly too fast at first and lose too much because of drag at that time, but fly fast enough to avoid great losses due to drag when you carry the centrifugal load, and if you reduce your speed at the top to the lowest value you dare to use. With regard to this last point it may be noted that at low speeds and high angles of incidence a small upward gust may make a considerable difference in the direction of the relative wind and even cause a stall. Thus, instead of supporting you more than still air, such a gust may have just the opposite effect, and if it is uneven on your wings it may throw you into a spin.

These points may readily be tested experimentally, though for obvious reasons a small fracto-cumulus cloud is a better object for the experiments than a telegraph wire. By this method, or by noticing how restricted the conditions are when the above theory indicates any gain by zooming, one may readily prove that under many circumstances a zoom does more harm than good, especially if the obstacle is a low one at a distance too short to allow the machine to get up a reasonable speed for the centrifugal

load to be carried. In my opinion, much of the zooming that is done is either useless or worse.

To solve the problem of steep descent by means of a series of skids or a long, steady side slip, we must consider several factors. One is the obvious increase of parasite resistance when the fuselage moves along any line but its axis; another is the effects of the eddies due to the side motion of the fuselage in reducing the lift of the wings on the leeward side, and a third is the increased "end effect" or escape of air past the ends of the wings from below, and converging motion of the air above the ends. This last effect is an obvious result of the increased pressure below the wings and reduced pressure above them and is greater if the wing is shorter, or if it is equivalent to a shorter wing as in a side-slip. As all these effects increase with increasing angle of the line of flight to the fuselage they can be used to give a readily adjustable drag and make it possible to regulate accurately the length of the glide. As the side-slip is steadier than the skids, it is easier to form an exact idea of one's course by this means and regulate it accordingly. Incidentally, we may notice that the same considerations serve to condemn the practice of side-slipping continuously in flying across the direction of the wind, so as to neutralize the cross component of the wind. The wings should be level and the course changed toward the wind.

With regard to the possibility of danger in these methods of landing, we must consider only what happens if the speed is reduced to the stalling point. Now it is obvious that the presence of eddies from the fuselage over a part of one wing tends to make it easier for the eddies to spread on it, and that the end effect of the wing that is to leeward (in the relative wind) is such as to weaken the lifting power of this wing especially. Moreover, on account of its weakened lift, as well as other factors in most designs, the ailerons on this wing must be turned down to hold this side up, and the ailerons on the other side are up. All these factors combine to make the leeward wing stall when the windward one is nowhere near the stalling point. And when it does stall, with the other wing still lifting normally, it will drop very suddenly, thereby increasing its angle of incidence still more, while the increased drag on it makes the ship spin round. The result of stalling from either a side-slip or a skid is therefore a

quick tail-spin. In the case of the side-slip the leeward wing is the upper one, and it falls suddenly below the other, drops backward and becomes the inner wing in the spin, while the other one keeps its low angle of incidence throughout the spin and does not stall at all, as one may readily prove by watching the tapes. In the case of the skid, the inner wing in the skidded turn is the leeward one, and we have in addition to the other factors the difference of speed of the two wings. The drop of the leeward wing is therefore even more sudden than in the side-slip, and in fact, forms a most spectacular trick on that account. Because of it, we may say that the practice of skidding to shorten a glide is not to be recommended, though a side-slip, if not made at too slow a speed, is quite safe.

As to the question of whether to stop the side-slip by righting the machine with the ailerons or by steering into the direction of the relative wind with the rudder, the above considerations show that the former method would mean a loss of speed before the slipping stopped, and the latter is the safer way.

We may now answer the questions of the advisability of skidding a turn off the wind, or of side-slipping till the last moment in landing. If we skid the turn off the wind, we would indeed avoid putting the two wings into different wind layers if the layers were flat and free from eddies. But this is too much to expect of them, and if there are eddies they will tend to throw the machine into exactly the type of spin that it tends toward because of the skidding. This practice must therefore be condemned without qualification. In side-slipping for a landing, on the other hand, if we do meet any such wind layers their chief result will be to level the wings and reduce the amount of slip, which does no harm. But as these are not the only types of irregular winds to be met near the ground, the air speed should not be reduced too near the danger point. As a French officer once said to me, "The first thing in aviation is to *fly*. To fly you must have speed. You *fly* into a house and live. You *fly* into a tree, and you sit there and smoke a cigar. But you *spin* into the field, and you are killed."

The problems on the effects of gusts of wind need not detain us long. The simple questions of the forces and accelerations when a gust is first struck are matters of finding the changes in the speed and direction of the relative wind, and the subsequent

motion involves stability considerations. The mathematical treatment of these has been given in detail by E. B. Wilson on the basis of the stability theory of Bryan and Bairstow, and even a qualitative treatment would be too long to insert here. One qualitative point that is of interest is that badly disturbed air, such as is found over hot sandy country, will tend to make the stream lines irregular and fluctuating, and produce more drag for a given lift, thereby requiring more power and greatly reducing the speed and climbing power.

THE ELEMENTARY THEORY OF STABILITY.

The theory of stability, from the pilot's point of view, is the answer to questions of this type: If the machine is flying steadily and is disturbed by a momentary gust, will it return to steady flight if I hold all controls fixed, and if so, how soon? Or if not, will it do so if I move only one control, the others being fixed? And which one? And what type of motions will occur? And how quickly ought the machine to return, if it does so at all? There is, of course, also the question of whether it would return to normal flight with the ailerons and elevators free instead of fixed, as some machines will. In machines with one motor the rudder can never be left free, because the secondary effects of the propellor torque would always turn the machine one way, so the question of a free rudder does not enter.

Of the various possible arrangements of the controls and resulting types of stability, we may define four as of the most practical value in piloting, as follows:

(*a*) Longitudinal, or pitching, stability. If a machine is made to pitch slightly, but does not yaw or roll, and the elevator is then held neutral, will it return to its initial elevation of the nose, or will it go either into a stall or a dive?

(*b*) Directional, or yawing, stability. If it is made to yaw slightly, but does not pitch, and the ailerons are so moved as to prevent rolling, and the rudder is then held in the position for normal flight, will it stop yawing and settle down to a straight course?

(*c*) Rolling stability, sometimes called "lateral" stability If it is made to roll slightly but does not pitch, and the ailerons are then held neutral while the rudder is so moved as to keep the axis of the ship pointed in a fixed direction, will it right itself?

(*d*) Complete lateral stability. If it is given any combination of slight rolling and yawing, but does not pitch, and both the ailerons and rudder are then held in positions for normal flight, will it return to normal flight?

One might expect at first that rolling and yawing stabilities, occurring in the same ship, would involve complete lateral stability, but as we shall see below, they do not. It is assumed in the question on pitching stability that the machine does not roll or yaw, and in the others that it does not pitch. For very small motions, this involves no outside interference, but for motions not very small there is usually enough connection between the types of motion to make it necessary to use the controls to prevent pitching if yawing or rolling occurs, and if large amounts of pitching occur the controls are needed to prevent the other motions.

The first problem is qualitatively simple. As noted above, the shift of the centre of pressure with speed is such as to produce instability in pitching. But suppose the horizontal tail surface, or "stabilizer," is large and set at a zero angle of incidence for a certain condition of flight, where the wings have a reasonable positive angle and the centre of pressure is at the centre of gravity. As the stabilizer is far back of the centre of gravity, it will act as a weather vane and tend to hold the ship to this angle of incidence, irrespective of its speed. Therefore, if the speed is too high for normal flight with this angle, the machine will nose up and then begin to lose speed, and if it is too low, the reverse effect takes place, the machine finally settling to a straight course at the proper speed for this angle of incidence and the proper angle of climb or glide to give this speed with the available engine power. The essential point is to have the tail carry little or no load, so that it will tend to bring the ship to the same angle of incidence at any speed, and have it large enough to do this in spite of the shift of the centre of pressure. The same thing could, in fact, be accomplished with a smaller tail set at a negative incidence, but then the correction of any deviation from a normal course would be too quick, and gusts near the ground would cause danger in landing. A large tail with no lift gives a slower correction and damps out any oscillations rather better.

With such a tail, a momentary pitching disturbance results in a combination of two oscillations, one so heavily damped as to be nothing but a "bump," and the other a long slowly damped

wave-like course, with higher speed in the trough of the waves and lower on the crests. Lanchester calls this long oscillation a "phugoid," and in 1894 he made model airplanes that he called "aerodones," based on practically the theory outlined above, and showed that they were longitudinally stable and would perform phugoids if left to themselves. A more exact mathematical theory has been developed by Bryan and Bairstow, as a fourth order differential equation, describing both oscillations and also indicating the large non-lifting tail as the condition for decreasing amplitude in the phugoid.

The mathematical theory indicates that a slight phugoid motion is sometimes stable at high speeds and slightly unstable at low. (See Hunsaker, "Dynamical Stability of Aeroplanes," Smithsonian Miscellaneous Collections, 1916.) Practically, however, if you try to hold the elevator fixed, by hand, the order of stability often seems to be just the reverse. The explanation of this is probably that you do not really hold it fixed. The greater rate of shift of the centre of pressure with speed at high speeds means a greater rate of change of the tail load if the elevator is fixed. Consequently, the lost motion and elasticity in the control wires and levers and in your muscles probably permits enough motion of the surfaces in response to this changing load to produce the apparent instability. In a ship with an adjustable "stabilizer" or horizontal tail surface in front of the elevator, you find the stability with the elevator left free to be of the same sort as that predicted by the theory. This example shows the importance of a clear and definite statement of the conditions of the problem if a definite answer is desired, and the importance a minor factor may sometimes acquire.

Yawing, or directional, stability is likewise a matter of weathervane action, but in this case with a vertical tail fin and rudder. But here, as we do not have any strong tendency to instability, like the shift of the centre of pressure, the weathervane surface can be made smaller. In fact, in birds it is not even present, being made up by the freedom of motion of the wings, though the horizontal tail surface always is there. The motion in the case of a momentary yawing disturbance in most cases is a single type of damped oscillation, of a period of 5 or 10 seconds, though at the stalling speed, as noted above, all lateral stability disappears. I have flown machines of one type where the yawing motion was

not oscillatory, but the machine would continue to skid indefinitely around a large circle, the speed of skidding neither increasing nor decreasing. In these machines the rudder and vertical fin were unusually small.

To give rolling stability we may use either a dihedral angle between the wings, retreating wings, or high vertical fins, as described in all the elementary treatises on airplane design. In any case, whether stability exists or not, the first rolling motion is damped out in a fraction of a second by resistance. This we might readily predict from the increased angle of incidence of the wing that is going down and the decreased angle of the other one. This leaves the ship banked up. If now, as we assumed above, the rudder is used to prevent yawing, the machine will side-slip downward and may or may not right itself. If it does, it will do so only very slowly, because of the great resistance to rolling motion. If the ship is excessively stable against rolling it will right itself fast enough to side-slip further and then come back again, making a damped oscillation, but in most ships the motion is dead beat. Whether it rights itself at all or tips further from the start, the rolling is always slow. Consequently, rolling instability is not ordinarily a source of danger, as yawing or pitching might be. It is, however, a convenience in a long cross-country flight, to be able to sit back with your hands on the cowl and steer by the rudder only, as you can in a ship that has both rolling and pitching stabilities with free controls. But if you make turns by the rudder only, as one may infer with little labor from the theory above, there are great losses of energy in skidding and side-slipping. And another point deducible from the theory is that any of the devices for securing rolling stability mean a great increase in the "end effect" on the wings at low speeds, and consequent loss of climbing power, and too much rolling stability means unsteady motion in gusty winds. Many recent models are therefore almost neutral as to rolling.

Now let us consider the question of complete lateral stability. If the machine is disturbed by a slight yawing motion only, the weathervane action of the fixed rudder will tend to produce the same damped oscillation that it would with the wings held level, and the motion will not differ very much from this. The only noticeable difference is that since both wings must lift almost

exactly the same (rolling moment of inertia being small) the wing swinging forward will take a smaller angle of incidence than the other, and consequently rise during the forward motion, while the other drops. The peculiar type of motion described here has been called by Hunsaker the "Dutch roll." This rolling motion introduces a turning moment which tends, in many cases, to retard the wing with the smaller incidence. This seems strange at first, but was deduced mathematically by E. B. Wilson, and may be qualitatively confirmed from the theory above with careful thought. The effect, however, is not ordinarily enough to make a very noticeable change in the period of oscillation, though it must make some. The ships mentioned above, that were neutral as to pure yawing, seemed to be slightly stable in the Dutch roll, but so slightly that the rudder was always busy in rough air and many pilots regarded them as liable to fall into a spin. This idea was not justified, but the continual work with the rudder was annoying at times. Now the Dutch roll may be called a fundamental type of motion, like the phugoid, because all the velocities, yawing, rolling and skidding, decrease in the same ratio as it dies out.

Another fundamental type of motion is obtained by an impulsive motion of the ailerons and rudder to cause a rolling motion, with a slight backward motion of the wing that goes down. This is always quickly damped, like the initial motion described under the heading of rolling stability, and in fact so quickly, that it is hard to tell what ratio of rolling to yawing constitutes the fundamental type in question. This motion is never oscillatory.

Finally, there is a curious spiral motion, consisting of a long slow turn somewhat overbanked, with a steady side-slip toward the centre. In this it is most difficult to get stability, or decreasing disturbance from straight flight, because of two factors tending to increase it. One of these is the greater lifting power of the wing on the outer side of the turn, due to its greater speed. In a steady turn this wing must be held down and the other one up by the use of the ailerons. But with the ailerons neutral the outer wing must tend to rise unless something prevents it. Consequently, if the machine is turning steadily and the rudder and ailerons are put in the neutral positions, the outer wing will begin to rise. The machine will then side-slip toward the centre; and

if the rudder is large enough to produce yawing stability it will then begin to yaw faster and then bank up faster still. ("Yawing" means any turn on an axis set vertically with respect to the ship, and does not necessarily imply oscillation as it does when applied to a sailboat.) These two tendencies work together, therefore, to produce spiral instability. But if the machine has rolling stability the same side-slip that produces quicker yawing will also tend to reduce the bank. And if it has great resistance to yawing due to vertical surfaces far ahead of and behind the centre of gravity, it will not start to yaw fast in obedience to a given side-slip. Bryan's fourth order differential equation for complete lateral motions predicts all the three fundamental types of motion just discussed. In it the criterion for spiral stability appears as the difference between two products, each of two "resistance derivatives." The two resistance derivatives in one product express the rolling moment due to yawing and the yawing moment due to side-slip, and the two in the other express the rolling moment due to side-slip and the yawing moment due to yawing (the last, of course, being a damping coefficient of yawing, and therefore negative). The theory therefore predicts exactly the type of performance observed in the air and qualitatively explained by these simpler considerations, and indicates the same conditions for stability.

As a matter of fact spiral instability, like rolling, produces only a slow growth in the motion involved unless the ship is of an extremely bad design, and it is therefore not worth sacrificing much else to correct. It is less important, for example, than the Dutch roll. The ships I spoke of above that were neutral as to yawing, with the wings held level, were also spirally neutral, and with all controls neutral they would circle indefinitely, side-slipping inward continuously. Some others that I have tried would do the same and have yawing stability, but many models with stability for both rolling and yawing are spirally unstable, and true spiral stability is very hard to obtain without too much of the same sacrifices that must be made for rolling stability.

CONCLUSIONS.

The factors involved in these qualitative stability considerations are not especially complicated, and are practically the chief factors that must be determined quantitatively in designing an

airplane according to the mathematical theory. As a matter of practical piloting, the chief value of the study of these points is in the fact that if the pilot understands why the machine performs the motions it does under these definitely specified conditions, and has picked out the factors involved in each and analyzed them carefully, he will know how to recognize their action in other cases, to correct them if necessary and to use them if possible, and the actions of the airplane will cease to be those of a capricious animal, and become as reasonable as anyone can wish them to be. To attain this understanding it is not necessary to go into all the details of the algebraic statements of these laws, but it is necessary to keep the fundamental principles of the wind forces in mind, and above all it is necessary to state definitely and rigorously the conditions of each problem and the factors involved in it.

In the study of the theory of acrobatics the problems are of a very similar nature, the chief additional factor being the changed character of the forces introduced when one wing is stalled and the other not, as in the tailspin. A detailed discussion of acrobatics is hardly necessary here, as no new principles or methods are involved and the chief object of this work is to point out the necessity for the type of analysis of the fundamental principles that is outlined above and the great need for rigorous thinking without arithmetic.

By this I do not mean to say that arithmetic has no place at all in flight, because, as noted above, the problems of navigation and long climbs involve its use, although even here I should say that only the simplest approximate rules are of much real value. Nor do I mean to imply that instruments for quantitative measurement have no use. In fact, I have spent many hours in the air experimenting on such instruments and am fully convinced that they can be of the greatest aid in problems of navigation and long climbs as well as in showing motor trouble in advance. But these problems are emphasized enough in the treatises on airplane design, and here I am concerned with the qualitative problems that are of at least as much importance, if not more.

They are a type of work that is sadly lacking in our physics text-books and courses, and consequently in the students. We try to cover so many topics in our courses that the student and even the teacher are almost driven to clutch at a formula like the proverbial drowning man, and with much the same result.

If physics is the study of inanimate things, then it *is* the study of things, and not of numbers; and if things choose not to lend themselves to numerical analysis, that does not mean they are not worth studying. And airplanes, as noted at the beginning of this paper, are not the only inanimate things that sometimes make this choice. If things as they are can be understood best by correct analyses of a few typical subjects, quantitatively where things lend themselves to quantitative work, and qualitatively but rigorously elsewhere, then let us change our courses to make such analyses.

Caking of Salts.—This phenomenon has been studied by T. MARTIN LOWRY (*Chemical Trade Journal and Chemical Engineer*, 1920, lxvi, 297–298). Marked caking of ammonium nitrate may occur when the crystals are dried in a commercial drier, or when the molten salt containing a small per cent. of moisture is poured at a temperature slightly above the melting point of the dry salt; distinct caking may take place if the milled salt be left under slight pressure all night. A change in the crystalline form of the salt liberates inclosed moisture which then cements the tiny particles. Mechanical disintegration may liberate moisture and thereby produce caking, but to a lesser extent. In an edge-runner mill, the moisture evaporates as rapidly as it is released by milling, and therefore has but slight effect; consequently, serious caking does not occur. The following compounds may undergo caking: Sodium nitrate, potassium nitrate, cupric nitrate, potassium chlorate, potassium perchlorate, potash alum, Rochelle salt, soda ash, common salt, borax, sodium sulphite, sodium hydrosulphite, sodium phosphate, citric acid, and tartaric acid. Certain directions are given for the prevention of caking: "Care should be taken to reduce to a minimum the number and amount of soluble impurities; when possible, the substance should be left in large crystals, as the fewer the number of points of contact, the smaller will be the tendency for the material to bind together; when a finer product is required the most satisfactory way of supplying it is in minute unground crystals; when a substance is specially required in a finely powdered form, there should be careful drying, with agitation after grinding; as far as possible the drying should be carried out at low temperatures; substances should not be packed hot unless all traces of moisture have been removed; steps should be taken to maintain a dry atmosphere during packing; care should be taken to prevent access of moisture to the substance after packing; and caking may be minimized by keeping the temperature as constant as possible during storage" J. S. H.

THE CONSTRUCTION DIVISION OF THE ARMY.*

BY
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THE subject upon which I am invited to address you this evening is the work of the Construction Division of the Army during the World War. This is a subject so far reaching in extent, embracing so many angles, and of such large significance, that I have devoted considerable thought to what phase of it I had best take up and what method of approach I should employ. In view of the fact that in 18 months the Construction Division completed or had under way 581 construction operations, located in every state of the Union, except Nevada, involving an expenditure of more than twelve hundred million dollars, it is manifestly impossible to give any detailed résumé of its operations, for its accomplishment is too vast to be made intelligible by the mere recital of statistics, and the spirit of its men and their remarkable teamwork is too elusive for the camera to record. Neither figures nor photographs can adequately tell its story.

The Construction Division of the Army is an independent staff corps. It has no relation to the Quartermaster Corps, nor to the Corps of Engineers, with both of which it is sometimes confused in the mind of the public. It is a separate entity, which had its genesis in the Construction and Repair Department of the Quartermaster General's Office. This small subdivision, before the war, was charged with the construction and repair work at the Regular Army Posts. In no year did it expend more than 15 million dollars. In 1916 it had prepared typical plans for temporary mobilization camps in view of possible trouble along the Mexican Border, but nothing had been done in anticipation of the extensive requirements made necessary by our entry into the World War.

Upon the declaration of war the immediate problem con-

* Presented at the joint meeting of the Institute and the Philadelphia Association of Members, American Society of Civil Engineers, held Wednesday, December 17, 1919, by Col. G. R. Solomon, Officer in Charge of Engineering Branch, Construction Division, U. S. Army.

fronting this Government was that of raising an army of millions and of providing accommodations for its housing and training. In the Regular Army Posts, scattered throughout the country, there was accommodation for less than 100,000 men in small isolated posts, totally inadequate for the training of men, in large groups. The task of providing camps and cantonments ready to receive the citizen soldiery as soon as it could be called to the colors was assigned to Colonel I. W. Littell, who was relieved of his duties as Chief of the Construction and Repair Division of the Quartermaster General's Office and placed in charge of the Cantonment Division. From this small beginning, with its force of three officers and less than 30 civilian assistants, there was developed the Construction Division of the Army. Its personnel was recruited almost entirely from civilian experts. Engineers, architects, construction men, material men, auditors and contractors were called to Washington and commissioned for a definite service. Every man was a picked man and his ability and reputation personally known to at least two members of the rapidly growing organization. At the signing of the Armistice there were 1429 commissioned officers in the Division, of whom less than a half dozen were officers of the Regular Army, and the civilian personnel totalled over 30,000 employees, and there had been employed on its projects more than 427,000 laborers.

With the growth of the Division came increased responsibility. Before the construction of the sixteen original army cantonments was well under way, the Division was directed to construct within two months' time sixteen additional tent camps for the National Guard, with a capacity of 684,000 men. Before any of these were completed, orders were received to build a Quartermaster training camp at Jacksonville, Florida, and ports of embarkation in the vicinity of New York, Norfolk and Charleston, so that the men when trained could be readily shipped to France.

On October 5, 1917, the Secretary of War directed that all construction work for the Army within the United States should be performed by the Construction Division. Under this order, work was done for every division and bureau of the War Department, involving every class of engineering construction, and costing more than 10 per cent. of the total expenditures made by this country for war. Because of the spectacular performance in connection with the construction of the camps and the publicity

given them by reason of their occupancy by men from all parts of the country, they are thought by the public generally to be the principal work done by the Construction Division. In matter of fact, their cost represents less than half of the total sum spent by the Division. In addition to housing accommodations for more than two million men, this Division built arsenals, storage depots, industrial plants, gas plants, proving grounds and other such projects for the Ordnance Department; hospitals, with a capacity of more than 121,000 beds, for the Medical Department; huge interior storage depots similar to the one in this city, and port terminals at Boston, Brooklyn, Norfolk, Charleston and New Orleans, for the Quartermaster Department; warehouses and flying fields for the Signal Corps and the Division of Military Aeronautics; mechanical repair shops for the assembling and repair of automobiles and trucks for the Motor Transport Corps; and embarkation and debarkation facilities for the Transportation Service.

A body of tremendous assistance to the Construction Division, especially in the early days of the war, was the Emergency Construction Committee of the Council of National Defense. Under the chairmanship of Mr. W. A. Starrett, of New York, later commissioned Colonel; Mr. Frederick Law Olmstead, of Boston; Mr. C. W. Lundorf, of Cleveland; Mr. M. C. Tuttle, of Boston, and Major William Kelley, of the United States Army, this committee laid down many of the fundamental policies for handling construction work. It was a "Ways and Means Committee," whose counsel was sought and valued. It was in part responsible for the wise decision to utilize every available construction agency which had been perfected by years of commercial competition, as a part of the working machinery of the Construction Division. By utilizing the large contracting firms of the country and their efficient organizations, it was possible to keep their trained personnel intact and to make available to the Government their experience and talent. There was the additional consideration of the necessity for stabilizing the economic and business life of the country and carrying these organizations through the period of war, rather than disrupt and destroy them by trying to organize their employees under direct Government control. The same policy was extended to include the consulting engineer, and on each large project there was employed an experienced engineer of national

reputation who, with his organization, took the fundamental plans supplied by the Washington office and adapted them to meet the local requirements of his job.

Having determined to use existing engineering and contracting firms, it became necessary to formulate a contract which would short-cut the peace-time red tape and procedure of the War Department and make it possible to get immediate action and quick results, at the same time relieving the contractor of many of the hazards growing out of the war which he would incur under a lump sum form of contract, but still protecting to the fullest possible degree the Government's interests. A number of well-established methods were considered and discarded; the lump sum contract, the lump sum contract with cost plus for changes and additions, the agency form of contract, and the unit price form of contract were all open to serious objection. They were not flexible enough to permit the changes in plan, the increase in size and scope of the work and the modifications in the type of construction, which it was known, would have to be made to meet the new and ever-changing requirements developed by experience at the front.

In no case when a construction project was begun, was the completed project clearly delineated or its final requirements known. I have in mind one job, which, when begun, was planned as a small project, costing a quarter of a million dollars, and which, before it was completed, was expanded a hundred fold and cost twenty-five million dollars. This is an extreme case, but the principle held good throughout all the work which the Construction Division did, and both its engineering and administrative organization, as well as its construction forces, had to be organized and made flexible enough to immediately adjust themselves to any change in requirements which new developments in the science of warfare might impose.

Twice the cantonment plans had to be materially altered after construction was well under way. First, because the regimental units and company quarters were laid out to fit the American Army organization as it existed previous to the war. General Pershing did not arrive in Europe until June 15, 1917. He immediately found that the experience of both the British and French Armies had demonstrated that a company of 250 men was a more convenient size for trench warfare than the smaller 150-man company

of the American Army, and the plans for the barracks buildings and regimental areas were changed accordingly. Again experience demonstrated that the health of the troops might be put in jeopardy by overcrowding and for that reason the Surgeon General revised his plans and required that at least 500 cubic feet of air space be provided in barracks and quarters for each man housed therein. To provide for such contingencies as these the contract for construction had to be of the utmost flexibility. The main point was to get started and get started immediately with the possibility of developing the details of the project as its requirements became more and more definite.

Due to the urgent necessity for speedy completion of the work, there was no time for drawing up detailed plans and specifications had it been practicable to make them. The job had to be finished in less time than it ordinarily took to prepare plans. The creation of a field organization, the drawing of plans, the procurement of the materials, the engineering work at the site and the actual building construction all had to go hand in hand and all had to be begun immediately. The only form of contract which would permit this method of procedure was the one adopted. It is generally called, in the War Department, the Emergency Form of contract. A more descriptive name, though perhaps a cumbersome one, is "the cost of the work with a sliding scale of percentage, limited by a fixed fee." Its critics have, since the Armistice, tried to discredit it by calling it the "cost plus 10 per cent. contract." This is indeed a misnomer for only on the smallest jobs, totalling less than $100,000 in cost, and prior to October, 1917, was a 10 per cent. fee paid. (After this date a fee of 7 per cent. was the maximum fee paid.) On the greater portion of the work not more than 4 per cent. or 5 per cent. was paid the contractor.

Briefly stated, the contractor was reimbursed for the actual cost of the project, plus a percentage fee for the services of his organization. This fee grew less and less as the cost of the job increased, until the maximum limit of $250,000 was reached, after which no more fee was paid, regardless of the size of the job. The plan worked well. Where a job was estimated at the time the work was started to cost $100,000 the contractor might receive a maximum fee of $10,000; if it cost less than the estimate, he received 10 per cent. of the actual expense; if it cost more than

the $100,000 estimate, he received only the $10,000; on work estimated to cost $250,000 a fee of 8 per cent. was the maximum allowed and so on down, until the percentage fee on a three and a half million dollar contract was 6 per cent. At the time each job was authorized an upset fee was fixed, based on the estimated cost, beyond which the contractor would not be paid. The contract definitely provided that in no case should the total fee paid on any job, regardless of its size, exceed $250,000. In this way a contractor might receive a $250,000 fee on a job costing $5,000,000, but he would receive no more than $250,000 if his job cost twenty million dollars.

After the contractor had paid out of this fee the cost of his main office and the salaries and expenses of the members of his firm engaged on the work, his surety bonds and the interest on the capital required to finance his job, only a small part of his gross fee remained as net profit. On the sixteen National Army cantonments the gross fee paid to the contractor ran between 2 and 3 per cent. of the cost of the work. On some of the larger jobs, because of the $250,000 maximum limit, it was not more than 1 per cent., whereas had these projects been let on a lump sum basis, under the hazard of war-time construction, the contractor would have been obliged to add from 10 to 25 per cent. to his estimate of cost to cover his profit and his contingencies. A criticism of this form of contract generally implies a lack of appreciation of the conditions under which this work had to be done. The fixing of an upset fee on each job, regardless of its size, beyond which the fee paid to the contractor could not go, had a tendency to check extravagancies or any desire to prolong the job. It was to the decided interest of the contractor to finish his work in the shortest possible time, to do it as cheaply as he possibly could and thereby establish his reputation for good work and thus win favorable consideration for additional work.

This contract has stood successfully against every assault and there has never been a successful refutation of the form used as protecting the interest of the Government and allowing the utmost flexibility and freedom of action. It must not be confused with an ordinary cost-plus-a-percentage contract, under which the more the job costs the more the contractor receives, for it was far from such.

The Secretary of War appointed a committee, including the

Presidents of the National Engineering Societies, the Chamber of Commerce of the United States, the Construction Employees' Association and the American Federation of Labor, to review every form of contract which might be used for war work, and compare it with the Emergency Form, to determine whether or not any other kind of instrument would permit the Government to carry forward its construction program to better advantage. They reported briefly as follows: "No reasonable objection can be pointed out by anyone possessing a full understanding of its equitable operations and practice, and finally this scheme possesses one qualification which must commend it to all thinking men: it permits starting actual work weeks and even months before the details are completely worked out and delineated and permits the Government to push the job at any speed it may elect, changing at will its plan and scope and paying only what the work actually costs, plus a fee which is so reasonable as to be above the reach of fair-minded criticism."

The organization plan of the Construction Division is a simple one. There is a central organization in Washington, which lays down the fundamental requirements for each project, procures the authority and funds for its construction and follows the work through from its inception to completion. The details of the job are handled in the field at the site of the work. They are directly under an officer called the Constructing Quartermaster, who is responsible to the Government for the satisfactory completion of his job and for the proper disbursement of funds. He is the commanding officer during construction and all other agents, both engineer and contractor, report to him. His organization is built up to meet the requirements of the particular project under his charge and is a miniature of the main organization in Washington, having its engineering, materials, administrative, accounting and labor departments. In cases where difficulties are experienced or where advice is needed, he takes the matter up direct with a Supervisor in Washington, who is the point of contact between the Washington Office and the field. This Supervisor has a group of jobs under his direction and sees to it that his several Constructing Quartermasters in the field are kept in daily touch with the material and labor situation, furnished plans, and that materials purchased directly by the Washington organization have clearance and are shipped to the jobs and that

all legal and auditing matters are in accord with Government practice. The Supervisor in turn reports to a Section Chief, who is generally responsible for the work of some particular bureau, such as hospitals for the Surgeon General's Office, ordnance plants, or aircraft work. These Section Chiefs and their groups of jobs make up the Building Division and report to the Officers in Charge thereof.

The Engineering, Contracts, Administrative, Accounting, Requirements and Procurement Divisions act as service sections for the Building and Utilities Divisions, furnishing to the field forces expert technical data which the requirements of the job demand. The work of these several service sections is fairly well indicated by their names. The Engineering Division is responsible for all engineering matters from the survey of sites to complete and detailed plans for buildings and utilities, water supply, sewage disposal plants, heating, lighting, camp sanitation and the like. The Contracts Division prepares the contracts and interprets them, and acts in a similar capacity to a general counsel of a large business organization. The Administrative Division is charged with the employment of civilians, adjusts all wages, the settlement of labor disputes and the clerical work in the Washington Office. The Accounting Division attends to the money matters, including the auditing and checking of the expenses of the jobs. The Requirements Division presents the requests for authority to the Secretary of War, through the Director of Operations, and secures the necessary funds. The Procurement Division keeps in touch with the markets of the country and mobilizes and arranges for the transportation of the huge quantities of building materials required for the many projects under the jurisdiction of the main office. The Building Division is responsible for the conduct of the actual operations in the field and during the War was the manufacturing department of the business, its finished project being camps, hospitals, ordnance plants, etc., with the other departments assisting it in its stupendous task. The Utilities Division maintains and operates the project after its completion. The present organization differs but little in its plan from that which was laid down at the beginning of the war and the basic principle then established has controlled its activities since its inception.

The Construction Division, during the period of its war activi-

ties, was the largest construction organization in the history of the world and the largest employer of labor. In addition to its commissioned and clerical personnel, its working force numbered 427,000 laborers, more than twice as great an army as that which fought at Gettysburg on both the Union and Confederate sides, and more than four times the number of our Regular Army at the time of the declaration of war. This construction force had to be housed and fed during the construction period and this in itself was no simple problem, for many of the sites chosen for the camps were located on remote and virgin fields without a single facility for the accommodation of the labor which must build them. The outstanding feature of this work was the magnitude of the operation combined with the speed of its accomplishment. The individual buildings which made up the project were in themselves neither intricate of design nor difficult of construction, but the task of assembling them into a complete whole within the short time available so that they might be ready to serve their purpose was one of the things that made victory possible. Upon the continuity of supply of men and munitions the destinies of the overseas forces were absolutely dependent. Once a project was conceived it took its place in a definite schedule and it had to be completed in accordance with that schedule, or else all of the arrangements of the War Department based upon its being ready to perform its function at a given time would have been thrown into confusion by the failure of one step in the process. Can you imagine the resulting confusion had the operation of the draft been delayed because these camps were not ready to receive the men, or what might have happened had the newly made soldiers not been able to sail for France because of the lack of embarkation facilities? The Construction Division was one Government agency which delivered the goods on time.

Previous to the War the several bureaus of the War Department did their construction work independent and ofttimes in competition with each other. After the camps and cantonments were completed and the advisability of concentrating construction under a single head had been so clearly proven, the Secretary of War delegated to the Construction Division all the construction work required in this country. Each bureau made known its requirements, plans and estimates were then prepared by the Construction Division, authority for the expenditure of the neces-

sary funds was secured from the Secretary of War, a contractor was recommended by the Council of National Defense and approved by this Division and the construction work immediately started. Full authority for every detail of the work was placed upon the Construction Division and it was held accountable only for results.

In order that you may appreciate some of the phases of the work a few words may be in order as to how the building of the National Army camps was carried out. There were 16 of these projects, whose location was selected by a special Board of Regular Army officers in May and June of 1917. The last site was not approved until July 6th. Upon each of these sites it was required to build a camp capable of housing 40,000 men and accommodating 14,000 animals. Each one of these camps had to be a self-contained community with every modern facility for the comfort and health of the men who would be trained there. Barracks, mess halls, lavatories, administration buildings, officers' quarters, storehouses, refrigerating plants and laundries had to be built, water and sewer systems installed, roads constructed and railroad tracks laid, and lighting and heating provided. Each camp was in itself a veritable modern city, costing from 8 to 12 million dollars, which had to be created from the ground up within the short space of three months. If you can picture in your mind what it would mean to have to provide in that short space of time housing accommodations for all the people in Philadelphia, while New York, Baltimore and Pittsburgh were all equally busy on similar rush work and therefore fighting for the available labor and materials and freight cars which your job required, you will have some idea of the size of the task and the difficulties involved.

The fundamental engineering principle laid down by the Washington Office for adaptation to the conditions in the field were based on both Army and Municipal experience in this country modified by information received from our Allies. The Town Planner and Landscape Architect, together with the Fire Prevention Experts, prepared typical layout plans, indicating the amount of space required for the various buildings and the arrangement of the regimental areas. The varying topography at the several sites made it necessary to adjust these typical layouts to fit the ground in the field. To give an idea of the size and character of a complete camp, Camp Grant at Rockford, Illinois, may be

taken as a fair illustration. This cost approximately $11,000,000 and has a capacity of 43,000 men and 12,000 animals housed in 1600 buildings. The water supply system includes 6 wells, 38 miles of pipe and a reservoir of 550,000 gallons capacity. The electric lighting system required 1450 miles of copper wire, 1200 poles and 35,000 incandescent lamps. About 50,000,000 feet of lumber was required for its construction, which was erected at the rate of 500,000 board feet per day. The Division Hospital has a capacity of 1000 beds. Camp Lewis, at American Lake, Washington, is one of the most beautifully located of all the cantonments and is even larger than Camp Grant. It cost, in 1917, about $215 per man to provide complete housing accommodation in the National Army Camp and about $88 per man in the National Guard tent camps.

The water supply for the camps presented another serious problem. It was determined that 50 gallons per capita per day should be allowed for each man in camp and 15 gallons for each animal. This is about 80 per cent. more water than was supplied to the British, French, Canadian, Belgium or German camps. The primary requisite, of course, was to provide a water of unquestioned purity and where there was any possible danger from pollution to filter and sterilize it before distribution. In some cases existing water works systems in the nearby cities were available but even in such cases the strictest sanitary control was exercised over the plant and many betterments and extensions made. In some cases these extensions were financed by the Government, the municipality reimbursing the Government for the expenditure in free water. Where water was purchased the average cost was approximately 8 cents per 1000 gallons. In many locations independent plants were built including the most modern pumping and filtration apparatus. In all, some 275 different water supply installations were made, involving construction of 1100 miles of pipe from six to thirty inches in diameter, 700 miles of service pipe, ¾ inch to 2 inches in diameter, with a combined pumping capacity of 650,000,000 gallons per day; the reservoir capacity in tanks was 67,000,000 gallons, while impounding reservoirs capable of holding 3,000,000,000 gallons were constructed; filter plants were built having a daily capacity of 40,000,000 gallons and more than 4,000,000 troops and 2,000,000 civilians were supplied with water. Up to date there has not been a single case of

typhoid fever or other water-borne disease attributed to the impurity of any water supply, designed, operated or controlled by the Construction Division, which in itself is one of the outstanding facts in the history of this war.

Owing to the shortage in iron and the need for this metal for munitions, cast-iron and steel pipe was not available for the camp water systems except in limited quantities. Wood-stave pipe of Canadian white pine and California redwood was used, resulting in a large saving, both in money and time of laying. California redwood tanks of 200,000 gallons' capacity were largely used for the storage of water, their cost was much less than either steel or concrete, and the time and labor required for their erection only a fraction of that necessary for steel or concrete reservoirs.

Hand in hand with the need for providing a safe water supply was the necessity for disposal of sewage and other wastes in the most sanitary possible manner. With populations ranging from five to sixty thousand men and with a density of population in many cases much higher than found in cities, it was necessary to take every possible sanitary precaution. Standard designs and general specifications for the construction of sewer systems and sewage treatment plants and for garbage incinerators and can-washing equipment were prepared in the Washington Office and turned over to the Supervising Engineer on the job for adaptation and execution.

The standard tanks for sewage treatment were the multiple compartment horizontal flow type, provided with cross baffles so as to facilitate sedimentation and to permit the withdrawal of sludge. The bottoms were pyramidal and where the effluent was discharged into a large stream, no other treatment than dosing the effluent with chlorine was required. In some cases sprinkling filters and secondary sedimentation tanks were installed. In designing the sewage treatment plants an allowance was made for 60 gallons per capita. In hospitals 150 gallons per bed, and 60 gallons for each attendant was assumed as the basis for design. More than 1000 miles of sewer pipe were laid, over 100 sewage disposal plants were built, with a combined capacity of 20,000,000 gallons. The total area of the sprinkling filters constructed is over 500,000 square feet. The cost of the tanks

complete, with filters, at each of the 40,000 men camps was about $200,000, or $5 per capita.

It early developed that the amount of grease in the kitchen waste was far in excess of that encountered in ordinary municipal sewage. To relieve the sewage of this excessive grease load and prevent its interference with the operation of the disposal plants, a special type of grease trap was developed by means of which it was possible to recover about 95 per cent. of the grease contents in the sewage. It was found that about 13 pounds per capita per year of grease valuable for commercial use could be obtained from the wastes from the kitchens. Much of the camp waste was of commercial value. Garbage stations were erected and the waste material carefully classified was generally separated into garbage, fats, grease, bones, bottles, tin cans, paper and manure and so much as was of value sold under contract to Waste Disposal Companies. Special incinerators were designed and built by the Construction Division to destroy the wastes which had no market value. In some cases piggeries were established and the camp garbage thus profitably converted into fresh meat for the Army. As a result the Government received over a million dollars a year income from what would otherwise have been a total loss.

Many of the ideas developed in connection with the sanitation and waste disposal work were original in character and will be a permanent contribution toward the science of sanitary engineering.

The necessity for providing roads to carry the heaviest possible traffic, after some experiment. led to the choice of concrete as the most suitable type of pavement, but other types were used, such as brick, gravel, macadam and bitulithic, where the materials could be quickly procured.

It may not be out of place to once more call attention to the tremendous decrease in the proportion of deaths from disease brought about by the intelligent supervision and exercise of stringent sanitary regulations during the present war. As a proof of the efficiency of such measures as pure water and proper sewage facilities, drainage, mosquito control, comfortable housing and adequate hospitals, it is interesting to compare the figures during this war with those of our previous wars: In the Mexican War the deaths from disease amounted to 110 per thousand men; in

the Civil War, this was reduced to 65 per thousand men; in the Spanish-American War, 26 per thousand, and in the Russian-Japanese War the deaths among the Japanese troops which at that time represented the highest attainment in sanitary practice was 20 per thousand.

In July and August, 1918, when the camps and cantonments were in full operation, the death-rate from disease was 2.8 men per thousand, which is less than half of the death-rate for men of military age in civilian life. The rate from the beginning of the war up to the outbreak of the influenza epidemic was less than five per thousand men.

One feature of the work of the Construction Division that contributed largely toward this remarkable record was the provision all over the United States of ample hospital accommodations. Plans were prepared in conjunction with the office of the Surgeon General, not only for the hospitals in each of the Divisional Camps, but for special hospitals at many other places, including those for the treatment of tuberculosis, shell shock, for reconstruction work and other special requirements growing out of service in the theatre of operations. Altogether accommodations were provided for 121,000 patients, 12,000 nurses, 34,000 enlisted men and 4000 doctors. Many of these hospitals were built on heretofore unoccupied ground and required in addition to the buildings the installation of the necessary sewers, water and electric lighting systems, roads, and railroads. The camp hospital buildings were generally of one-story wooden construction connected by closed corridors so that patients might be readily wheeled in roller chairs from one building to another. These corridors were cut off from the main buildings by fire walls to prevent the spread of possible fires. Provision was made for every appliance of the modern hospital. X-ray laboratories, bacteriological laboratories, hydrotherapeutic wards and the most complete operating rooms and special laboratories for research work were installed. As the war progressed, the hospital plans were modified and terra-cotta block and stucco on metal lathe substituted for wood, and the buildings made two and three stories in height, thus bringing the units closer together and facilitating administration. At a number of the Regular Army Posts departmental hospitals were established, using the original post hospital as a nucleus and remodelling other buildings to meet the requirements and at certain

places throughout the country general hospitals, some of them containing from 2000 to 4000 beds, were constructed. Such commercial buildings as the old Siegal-Cooper store and the Grand Central Palace in New York were converted and made into large reception hospitals for the sick and wounded soldiers returning from overseas. At Ashville, N. C., and Denver, Colorado, special hospitals were constructed for the treatment of tuberculosis and other lung troubles.

The German drive in the spring of 1918, with its resulting large number of casualties, made it evident that a decided increase in the hospital accommodations would have to be provided immediately. There was no time to build new construction and in consequence a number of private buildings, such as museums, industrial plants, the Ford automobile factories and properties of like nature were taken over and converted by the Construction Division into reasonably satisfactory hospitals. In all, the Construction Division provided through new construction, purchase or remodelling a total of 294 hospitals, costing approximately $128,000,000. These ranged in cost from $750 per bed up to $2000, depending upon the isolation of the site and the character of construction.

Practically all of the buildings in the camps were of frame construction and therefore very inflammable. The fire hazard in the camps and hospitals was one which caused a great deal of concern until the effectiveness of fire prevention measures and inspections was so clearly demonstrated. A number of fires have started, but in only three cases has the fire spread beyond the buildings of its origin. The records for the year of 1918 show that the per capita loss by fire throughout the United States was $2.70, whereas the total per capita loss at the various Construction Division activities for the year ending June 30, 1918, was only 67 cents.

Of all of the construction projects, those built for the Ordnance Department are of the greatest interest, embracing as they do many new problems of construction and manufacture, plant layout, and shop arrangement. There were sixty of these projects costing a total of $175,000,000. One of the largest is the Proving Ground at Aberdeen, Maryland. Here are accommodations for 8000 men, a plant 165 feet wide and 500 feet long for assembling gun carriages and mounts for artillery and the

largest machine shop in the United States. The reservation contains 35,000 acres of land with facilities for every conceivable test, which may be desired of the many different types of guns and munitions developed during the war. There is also a bombing field where airplanes may practice aero bombing and 4000 acres are given over to the manufacture and testing of gas shells. This latter area is known as Edgewood Arsenal and its facilities cost approximately $30,000,000. There are quarters for 10,000 men and a gas-filling plant with a capacity of 120,000 loaded shells per day. Here mustard gas, phosgene, caustic soda, picric acid and other weapons of chemical warfare were produced on a large scale.

Explosives from their very nature must be stored by themselves and far away as possible from thickly settled sections, and at the same time this storage must be convenient to railroads and docks so that the contents of these magazines could be delivered to ocean-going vessels without unnecessary handling. The difficulty of finding such sites which were suitable for such construction within reasonable distance of deep water and rail facilities was apparent at the outset. Five of these projects were located along the Atlantic Coast, one at Metuchen, N. J., Pedricktown, Del., Pig Point, Va., Curtis Bay, Md., and Charleston, S. C. The Raritan Arsenal, which is at Metuchen, N. J., is the largest of these projects. This reservation comprises 2200 acres of salt marsh, which to prevent its submersion at high tide, had to be protected with a dike around the entire reservation. The soil itself was such that every structure erected had to be supported on piles. An Ordnance School was also located at this point with accommodations for 10,000 men. Fifty miles of railroad were required and a dock of 2000 feet in length with warehouses and other facilities were provided at a cost of about $14,000,000.

Bag-loading plants were another development made necessary by the War. Guns up to, and including 4.7 calibre, used ammunition in which the explosive is loaded in a metal cartridge case, similar in appearance to small arms ammunition, but guns of larger size used what is known as unfixed ammunition, that is, the powder is packed in silk bags of the diameter of the gun and after the projectile is placed in the bore of the gun a bag or number of bags, depending on the size of the gun, are loaded into the breech to form the propelling charge. The filling of these

bags must be done with the utmost accuracy, after the explosive itself has been carefully blended in order that no variation in the propellant force of the charge may occur. Three of these plants were constructed, one at Woodbury, N. J., one at Tullytown, Pa., and one at Seven Pines, Va. Because of the character of the work and the danger incident to the operation of the plant, these had to be as isolated as possible. So that complete quarters for the employees, many of whom were women, had to be built to provide for the operating personnel. These plants involved many new problems of engineering details and yet they were completed within three months' time.

Practically all of the shipping facilities required for the War were under the direction of the Shipping Board; the Construction Division, however, built and placed in operation 276 barges and lighters for use in handling supplies in connection with the Newark Terminal and for the loading and transportation of munitions from the Pig Point and Curtis Bay Storage Depots to the outward-bound ships.

At the beginning of the war, construction pertaining to the Air Service was under the jurisdiction of the Signal Corps, but after October, 1917, the Construction Division began taking over the construction work which was then in progress and after the early part of 1918 did all of this work. Flying fields were established in many parts of the country and housing provided for their personnel. Special buildings were constructed for housing of dirigible balloons and there is now in course of construction at Langley Field, Virginia, the largest dirigible hangar in the world. The R-34, which made the Trans-Atlantic flight, is 78 feet in diameter. This new hangar will accommodate a dirigible 100 feet in diameter and still leave space in the clear for a 16-foot car. Balloon schools were also constructed at Lee Hall, Virginia, and Arcadia, California, and used for the training of aerial observers. In the design of the dirigible hangars which are 168 feet high and 680 feet long, the problem of the door design is a difficult one. These doors are 70 feet in height and 40 feet wide. Their structural makeup and the method of opening them when they are in place, is one of considerable interest to a structural engineer, as well as the large amount of bracing required to withstand the heavy pressure of the wind against such a large surface.

For the Motor Transport Corps, maintenance and repair shops were constructed for assembling tanks, tracks and trucks used in connection with the Mobile Artillery, as well as for the ordinary passenger automobile. At Baltimore, Atlanta, and San Antonio, large projects for this purpose included enormous shops and garages and training schools. The buildings are fitted with the finest types of machine tools, cranes and other equipment and compare favorably with the most up-to-date automobile factories.

While the activities of the Construction Division have been confined to this side of the Atlantic, a notable exception may be mentioned in the case of the refrigerating and cold storage plants, designed, purchased, and shipped to France. Immediately upon the assemblage of the necessary materials for these plants, the Construction Division also organized the personnel for their operation. When the United States entered the war, there was available for the use of the American soldiers in France a storage capacity of only 750 tons of beef. This was later increased to 4000 tons capacity. During the same time the Construction Division provided in this country a capacity for 24,000 tons of beef. Owing to the distance that this beef had to be transported, a sharp freezer plant had to be provided where chilled beef could be hard frozen at a temperature of 15 degrees above zero in order to make it easy and safe for transportation. To meet this emergency, the Construction Division erected at Chicago the largest sharp freezer plant in the world. It is the most modern type of concrete and brick construction, insulated throughout with cork. It has a daily freezing capacity of 1400 tons, equivalent to 5000 animals, and a storage capacity of 14,000 tons of frozen beef.

Refrigerating and ice-making plants were designed and constructed at many of the camps and hospitals, but these were generally small in size, being designed to produce from 50 to 200 tons of ice per day, adequate for the army population of their particular locality.

Among the largest projects built by the Construction Division are the huge terminals at Boston, Brooklyn, Norfolk, Charleston and New Orleans. In them was concentrated the vast store of materials required by the overseas forces. Here these supplies were collected and loaded on ships. Tributary to these embarka-

tion terminals or Army Supply Bases were interior Storage Depots located at important railroad junction points and convenient to the great manufacturing centres of the country. Depots of this character were established at Philadelphia, New Cumberland, Pa., Schenectady, New York, Columbus, Ohio, St. Louis, Chicago, Jeffersonville, Ind., Pittsburgh and Baltimore. They provide a total storage space of 12,000,000 square feet.

These Army Supply Bases may be described as a combination railroad terminal and storehouse for the protection of merchandise and its transshipment to ocean-going vessels. The Boston Base is eight stories in height and is 128 feet wide and 1628 feet long. It has a storage space of 2,750,000 square feet. This building is paralleled by a wharf shed of the same length, two storied in height, while at the outer end of the 4000-foot pier, carrying these buildings, are two upper sheds, each 924 feet, by three stories. The terminal yard includes 30 miles of railroad track, extending to and through the various buildings, as well as along the sides of the dock. This huge project was built in five months and cost 25 million dollars. At Brooklyn there are two 8-story concrete warehouses, each 980 feet in length, one being 200 and the other 300 feet in width. These buildings contain four million square feet of storage space. Serving them are three double-deck piers, each 150 feet in width and 1300 feet long, and an upper pier 60 feet wide and 1300 feet long. The storage tracks will accommodate 1300 freight cars and the docks permit twelve 800-ton ships to be loaded at one time. With the mechanical equipment it is possible to load a vessel in 24 hours. This project was completed in approximately one years' time, and cost $28,000,000.

The Norfolk Base contains two million square feet of storage space, a mile of dock and terminal tracks for freight cars. This project required the reclamation of 217 acres of mud flats, the building of concrete pile bulkhead, and the filling in with material removed from the harbor to give the required depth to accommodate deep draught vessels. Here a cantonment was erected for a regiment of stevedores and a battalion of guards, including a 120-bed hospital. This project was completed in about 12 months' time and cost $25,000,000.

The Army Bases at Newark and at Charleston, S. C., are the one-story type and similar to Norfolk, while that at New Orleans was of reinforced concrete and comparable with the Brooklyn and

Boston projects. These Army Supply Bases and the Interior Storage Depots have a combined storage capacity of 27,502,300 square feet. With an additional 2,176,000 square feet of storage capacity and open sheds, an area equivalent to a building seventy feet wide and eighty-one miles long, the docking space is capable of accommodating 65 ships at one time. Eight hundred and forty-four miles of railroad track and 1061 miles of concrete road serve these projects.

This, in brief, is an outline of the scope of the work done by the Construction Division. It is a remarkable fact to my mind that such an organization could be suddenly created and built up in a period of 18 months into the greatest construction outfit of all time, and that, by the welding together of peace-trained engineering and building organizations into a military unit with a single purpose, it could undertake and carry to successful completion a building program on a vaster scale than was ever before conceived in the mind of man. Out of its success there is engendered a new feeling of respect in the Army for the capacity of the civilian scientist, engineer and constructor and his value as a military asset, a feeling that he may be depended upon in any future emergency, to quickly divert his talents to warfare as effectively as he follows his normal, peaceful pursuits, for he has proven his worth and established his war value. His contact with the Army has also given him a new viewpoint which enabled him to better sense the military problem of the country and to contribute understandingly towards its solution.

Much of the work which the Construction Division did was of necessity a part of the waste of war, in the same sense that the powder shot on the battle front was waste, and it has no permanent value as a peace-time asset, and yet there are many of its projects which have already become an important part of the economic fabric of our nation. The Army Supply Bases at Brooklyn and Boston, and at Norfolk, Charleston and New Orleans represent the finest port terminal facilities in the world. In connection with an American Merchant Marine, they will become as useful for peace as they were in time of war, and they were designed and built with this thought in view.

Against the huge sums spent by the War Department, there is the offset of such improvements as these terminals. In many other localities there have been provided new roads, new manufac-

turing developments, enlargement of electric, steam and gas plants, provision for better sewage disposal and adequate water supply, rehabilitation of both steam and electric railroads, the establishment of steamship and railroad terminals, the drainage of malarial areas and reconstruction of buildings and communities to improve living conditions, all of which the demands of war forced into existence, and which now remain as a vast asset to the country. Thus have our "shields been beaten into plowshares and our swords into pruning hooks."

To few men have fortuitous circumstances brought such an experience as has come to me as Chief of the Construction Division. I have felt a thrill in directing the efforts of this great creative body of men. I have seen the engineer, the highly specialized technical expert, the contractor, the auditor, the engineer, the clerk and the laborer rise at their country's call and for the time being throw off the hampering jealousies and restrictions of their normal life and accomplish the impossible; and the credit for this achievement rests largely upon men, such as you, who make up the membership of Franklin Institute, the American Society of Civil Engineers and the other national technical associations, and who more and more are dominating the future course of this great nation.

Electrolytic Chromium. (Advance sheets of a paper by GEO. J. SARGENT, Res. Chemist, from the 37th general meeting of the Amer. Electrochemical Society, Boston, April 8–10.)—Brief allusion is made to the history of the deposition of chromium, including some unpublished work by Skillman of Cornell University. Details are given of the various mixtures of chromic sulphate and chromic acid showing that the yield of metal is greatly increased by the presence of chromic sulphate. Comparisons of results with rotating and stationary cathodes and of the differing temperatures and strength of solution are tabulated. Very good deposits of chromium were obtained in some of the experiments, low temperatures yielding fair ampere-hour efficiency at comparatively low current density. The chromium deposit is very resistant to corrosion by ordinary influences, for which reason the author concludes that such plating has important commercial possibilities.

H. L.

Electrical Supply in Small Dwellings. (*Electrician*, Feb. 13, 1920.)—In Great Britain Messrs. W. T. Henley's Telegraph Works Company is making a special point of lighting workmen's houses by electricity. In one installation the tenant is charged 28s. per annum for a six-room house with only one lamp in a room. The cost of wiring is much reduced by a twin metal sheath system and by using series systems in some and parallel systems in others. The cost of wiring in 1914 was 7s. 6d. per light and the cost of maintenance has proved to be small. G. F. S.

Testing Roads for Heavy Travel. (*Weekly News Letter, U. S. Department of Agriculture*, vol. vii, No. 32, p. 8.)—State highway departments are vitally interested in the successful outcome of comprehensive experiments and tests now being made by the Bureau of Public Roads of the United States Department of Agriculture. One State engineer recently declared that millions of dollars in his State are involved in the proper design of road surfaces, which make up one of the problems being investigated by the Federal engineers.

The coming into general use of the heavy motor truck has practically revolutionized the science of road-building. Big new problems came when loads weighing 10 to 15 tons took the place of vehicles that placed a weight one-fourth as much or less. The roads built ten years ago were constructed before this fact could be realized—which is one of the reasons why many "permanent" roads have proved to be impermanent.

One of the testing experiments being made by the Federal Bureau involves the use of a 49-section roadway in the Arlington farm, owned by the Department of Agriculture. Each section was built from a different type of material, or with a different method of construction. The same use is given to each section, so that eventually the type of construction best suited to heavy traffic will prove itself. R.

Research Grant.—The American Pharmaceutical Association has available a sum amounting to about $450, which will be expended after October 1, 1920, for the encouragement of research. This amount, either in full or fractions, will be awarded in such manner as will in the judgment of the A.Ph.A. Research Committee produce the greatest good to American pharmaceutical research.

Investigators desiring financial aid in their work will communicate before May 1st with H. V. Arny, Chairman A.Ph.A. Research Committee, 115 West 68th Street, New York, giving their past record and outlining the particular line of work for which the grant is desired.

The committee will give each application its careful attention and will make recommendations to the American Pharmaceutical Association at its meeting in Washington, May 3d to 8th, 1920, when the award or awards will be made.

THE CHARGE ON THE ELECTRON AND THE VALUE OF PLANCK'S CONSTANT h.*

BY

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LEWIS AND ADAMS (*Phys. Rev.* (2), 3, 92, (1914) from a theory of ultimate rational units, *i.e.* by a kind of dimensional reasoning, have derived the following relation between Planck's constant h and the electron charge e.

$$h = \frac{e^2}{c} \times 32\pi^3 \sqrt[3]{\frac{\pi^2}{15}} \quad \ldots\ldots\ldots\ldots \quad (1)$$

where c is the velocity of light (2.9986×10^{10} cm. per sec.). If we take for e the value 4.774×10^{-10} e.s. units as determined by Millikan (*Phys. Rev.* (2), 2, 143, 1913) this gives

$$h = 6.560 \times 10^{-27} \text{ erg seconds.}$$

In a recent paper R. T. Birge (*Phys. Rev.* 14, 361, 1919) has calculated h in seven different ways and obtains as the most probable value

$$h = 6.5543 \times 10^{-27}.$$

Every method of determining h, however, involves the use of e so that any error in this quantity produces a corresponding uncertainty in h. Sommerfeld in his recent book on atomic structure (*Atombau und Spectrallinien*, Nov., 1919) has given a new relation between h and e in terms of the Rydberg constants obtained with hydrogen and helium. From Bohr's theory, taking into account the masses of the nuclei of the atoms, and by comparing the spectra of hydrogen and helium, he is able to calculate the value of e/m with very great accuracy (here m is the mass of the electron). He obtains

$$e/m = 1.7686 \times 10^7 \text{ e. m. units,}$$

$$\text{or } c \times 1.7686 \times 10^7 \text{ e. s. units.}$$

* Communicated by the Author.

Besides being based upon the spectroscopic wave lengths, this value involves a knowledge of the ratio of the atomic weights of helium and hydrogen (4.000 : 1.008). The relative error in e/m, however, is only about one-third as great as that in the ratio of the atomic weights. Sommerfeld has furthermore derived the relations

$$e = \frac{\alpha^3 c^2}{4\pi N_\infty (e/m)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where

$$\alpha = \frac{2\pi e^2}{hc} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Here N_∞ is the wave number corresponding to the Rydberg constant for an infinitely heavy nucleus. It has the value

$$N_\infty = 109737.11 \text{ cm.}^{-1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

These equations together with the Lewis and Adams relation enable us to calculate a new value of the electron charge e. Combining Equations 1 and 3 we find

$$\alpha = \frac{1}{16\pi^2} \sqrt[3]{\frac{\pi^4}{15}} = 0.0072798 \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

Substituting this together with the values of N_∞ and e/m in Equation 2 gives

$$e = 4.745 \times 10^{-10} \text{ e.s. units} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

while this value substituted in (1) gives

$$h = 6.481 \times 10^{-27} \text{ erg seconds.}$$

This value of e is about 0.6 per cent. lower than that given by Millikan, who estimates the accuracy of his result as 0.2 per cent. However, Millikan's determination has never been checked by any independent method of comparable accuracy, so it seems possible that a constant error of the above magnitude might have affected his results. The value of h given by Equation 7 is 1.2 per cent. lower than the value calculated by Birge but this results merely from the different value for e. The following table gives the values of h calculated from the seven sets of data used by Birge: first, using Millikan's value $e = 4.774$; and second, using the value $e = 4.745$.

Determinations of h.

Method	Dependence on e.	$e=4.774$	$e=4.745$
Stefan-Boltzmann Constant	$e^{4/3}$	6.551	6.497
Wien Constant c_2	e	6.557	6.517
Bohr-Sommerfeld theory, Equations 2 and 3	$e^{5/3}$	6.548	6.481
Einstein's photo-electric equation	e	6.578	6.538
Quantum relation for X-rays	$e^{4/3}$	6.555	6.501
Lewis and Adams theory	e^2	6.560	6.481
Quantum relation for ionization potentials	e	6.579	6.539
	Average	6.555	6.507

The values of h calculated from $e=4.745$ are consistently smaller than those based on Millikan's value, but they agree among themselves within the probable experimental error. In any case the results do not warrant the conclusion that the Lewis and Adams or the Bohr-Sommerfeld theories are not rigorous. Unless one of these theories is incorrect or incomplete, however, the values of e and h represented by Equations 6 and 7 should have a much higher accuracy than any of the other experimental determinations given in the above table. Under these conditions it seems desirable that new determinations of the electron charge should be made, especially if new methods can be developed.

An Experimental Determination of the Inertia of a Sphere Moving in a Fluid. GILBERT COOK. (*Philosophical Magazine*, March, 1920.)—Sir G. G. Stokes showed that a solid body moving in a fluid of infinite extent has its inertia apparently increased by the effect of fluid pressure. This effect became of interest in war time in connection with the theory of oscillating mines. A spherical mine-case 38.2 inches in diameter, ballasted so that its weight in water was only one pound, was allowed to fall freely through the water in a tank 15 feet in diameter and 30 feet deep. The motion was automatically recorded and the velocity and acceleration were calculated. When the acceleration is plotted against the square of the velocity the points lie close to a straight line. The faster the mine sinks the less is its acceleration. When the apparent inertia was computed it came out equal to 1.46 times the ordinary mass of the case.

G. F. S.

Quotations from the Diary of Samuel Pepys on the Weather. (*Quart. Jour. Royal Meteorol. Soc.*, January, 1920.)—It is now recognized that loud sounds are surrounded by zones in which they are inaudible. Beyond these come other areas in which the sounds may once more be heard. Under date of June 2, 1666, Pepys records that he went "into the Parke, and there we could hear the guns from the fleete most plainly." Two days later, "so walking through the Parke we saw hundreds of people listening at the Gravell-pits; and to and again in the Parke to hear the guns, and I saw a letter dated last night, from Strowd, Governor of Dover Castle, which says that the Prince (Rupert) come thither the night before with his fleete, but that the guns which we writ that we heard, it is only a mistake for thunder; and so far as to yesterday it is a miraculous thing that we all Friday, and Saturday and yesterday, did hear everywhere most plainly the guns go off, and yet at Deale and Dover to last night they did not hear one word of a fight, nor think they heard one gun. This makes room for a great dispute in philosophy, how we should hear and they not, the same wind that brought it to us being the same that should bring it to them: but so it is." These observations are in agreement with recent experience during the war.

G. F. S.

The Effect of High Temperature, Humidity and Wind on the Human Body. (*Quart. Jour. Royal Meteorol. Soc.*, January, 1920.)—Men die in the desert from the effects of the simoom, a strong, hot and very dry wind. The explanation offered is this: "Because, therefore, the bodily gain of heat by convection from the air increases as the strength of the wind increases, and because the human body cannot perspire above a certain maximum rate, it is easy to see that to each air temperature above blood heat there must, theoretically, at least, correspond a certain critical value of the wind velocity, which, if exceeded, must produce a net gain of heat to the body. Also, the lower the air temperature the higher will be the critical wind velocity at which conditions become unlivable. Under actual atmospheric conditions this limit appears never to be exceeded except in an exceptionally hot and dry wind."

G. F. S.

Wireless Network for the British Empire. (*Electrician*, March 12, 1920.)—Marconi's Wireless Telegraph Company has proposed to the Imperial Wireless Sub-committee to establish a network connecting Great Britain with all other parts of the Empire, including ships at sea between latitudes 60 N. and 50 S. Twenty-six main-trunk stations would be built, five of which would be in Great Britain. The staff, some thousands in number, would all be British subjects. The white members would belong to reserve military or naval units. G. F. S.

THEORETICAL MAXIMUM PRESSURE DEVELOPED IN OWN VOLUME BY THIRTEEN MILITARY EXPLOSIVES.*

BY

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DURING the World War, the Explosives Experiment Station of the Bureau of Mines carried out at the request of, and in coöperation with, the Ordnance Department of the U. S. Army, physical tests of the different explosives used for shell-loading, bombs and similar purposes. Among the different tests carried out, one of the most important, if not the most important test, is the Theoretical Maximum Pressure Developed in Own Volume, as this test shows directly the power available in the explosive for demolition purposes and shell fragmentation, and correlated with the rate of detonation of the explosive, is of great value in selecting the explosive for any desired purpose.

The maximum pressure of an explosive in its own volume is the pressure an explosive would exert if exploded or detonated in a space that it fills completely, all the heat set free by the chemical reactions that take place being retained by the products of the explosion. A part of this heat is absorbed through the confining surface. By varying the confining surface, its heat-absorbing effect is measured and combining this measurement with the recorded pressure, the total pressure is calculated.

The Bichel pressure gauges are used for this purpose. The volume of the gauges is 15 litres and the cooling surfaces used are (*A*) 3914 square centimetres, (*B*) 6555 square centimetres, and (*C*) 7624 square centimetres. An indicator gauge similar to a steam indicator gauge on the Bichel pressure gauge records the pressure on a revolving drum.

The pressure in own volume is computed by the formula

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$M = \frac{VPS}{W}$ in which V represents the volume of the Bichel gauge, which is always 15,000 cubic centimetres; S, the specific gravity of the material and W the weight in grams of the charge used in the test. P is determined by means of the formula $P = 1.911A + 0.5B - 1.411C$ in which P represents the pressure with elimination of cooling surface and probable error. This formula expresses the geometrical relation obtained by plotting the average pressure developed in two tests agreeing within 5 per cent. for each cooling surface against the area of the cooling surface, the line drawn through the three points being extended to the ordinate or zero cooling surface. By plotting the pressures against the cooling surfaces the effect of the cooling surfaces is determined and eliminated.

In making the tests, 200 grams of the explosive was loaded in an 8-oz. glass bottle and a No. 8 electric detonator embedded full length in the charge. A layer of dry plaster-of-Paris was then placed on top of the explosive and detonator, after which the bottle was sealed with wet plaster-of-Paris, which was allowed to set before making the test. The prepared charge was then exploded in the Bichel pressure gage evacuated to 50 millimetres pressure.

Samples $M - 2302$[1] of 80/20 amatol (acutally 85/15 amatol), $M - 2303$ of 60/40 sodatol, $M - 2325$ of trinitroxylene and $M - 2344$ of trinitronaphthalene would not detonate completely under the above conditions. The method of preparing the charge was then modified by inserting in the explosive charge a 24-gram booster of tetryl ($M - 2326$) packed in a test tube. The No. 8 electric detonator was embedded in the booster charge. The bottle was then sealed as above, and exploded in the Bichel gauge evacuated to 50 millimetres pressure.

Sample $M - 2307$ of ammonium picrate would not detonate completely in vacuum with a booster either of tetryl or picric acid. Acordingly, the test was carried out at atmospheric pressure in the Bichel gauge, using a picric acid booster ($M - 2308$).

The tests were usually made in duplicate within 5 per cent. But on certain explosives, where irregular results were obtained,

[1] Record number on office key-card, Bureau of Mines.

in spite of every precaution the average of all tests was taken as giving the more accurate result.

In calculating the results of those explosives where a booster was used the effect of the booster was eliminated from the value for P (pressure eliminating the effect of cooling surface), as follows: $P = P_1 - P_2$ where P_1 = pressure (of explosive and booster) after elimination of surface influence P_2 = pressure of booster after elimination of surface influence (9.287 kilograms per square centimetre for 24 grams tetryl, 8.642 kilograms per square centimetre for 24 grams picric acid).

As density has a very important effect on the theoretical maximum pressure, and as these explosives may be used at widely varying densities, the results of each explosive are given in a table showing the theoretical maximum pressure for densities of loading varying over the limits which may be used.

The details of the tests are as follows:

M–2302 of 80/20 amatol (actually 85/15 amatol).
24 gram booster of tetryl (*M*–2326).
Indicator spring 0.32 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
March 14...	*P*–1721	200	1.02	36.50[b]	91.25	*A*	
March 14...	*P*–1723	200	1.02	30.25	94.53	*A*	
March 14...	*P*–1722	200	1.02	30.75	96.09	*A*	93.96
March 14...	*PP*–2301	200	1.02	28.75	89.84[a]	*B*	
March 14...	*PP*–2302	200	1.02	26.00	81.25	*B*	
March 14...	*PP*–2303	200	1.02	26.25	82.03	*B*	81.64
March 14...	*PP*–2304	200	1.02	27.75	86.72	*C*	
March 14...	*PP*–2305	200	1.02	24.00	75.00[c]	*C*	
March 17...	*PP*–2306	200	1.02	26.50	82.81	*C*	84.77

[a] Not included in average. No apparent reason for high result.
[b] Indicator spring 0.40 millimetres = 1 kilogram per square centimetre.
[c] Not included in average. No apparent reason for low result.

$P = (1.911A + 0.5B - 1.411C) - 9.287 = 91.48$ kilograms per square centimetre.

TABLE I.

Theoretical Maximum Pressure in Own Volume of Sample M–2302 of 80/20 Amatol (actually 85/15 Amatol) at Densities of Loading Varying from 1.30 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
1.30	8919	126860
1.35	9262	131340
1.40	9605	136610
1.45	9948	141490
1.50	10292	146390
1.55	10635	151270
1.60	10978	156150

M–2303 of 60/40 sodatol.

24 gram booster of tetryl (*M*–2326).

Indicator spring 0.32 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
March 19...	*P*–1726	200	1.21	28.25[a]	70.62	*A*	[redacted]
March 19...	*P*–1727	200	1.21	27.50[a]	68.75	*A*	69.68
March 18...	*PP*–2309	200	1.21	20.00	62.50	*B*	
March 18...	*PP*–2310	200	1.21	21.50	67.19	*B*	
March 18...	*PP*–2311	200	1.21	19.50	60.94	*B*	
March 21...	*PP*–2320	200	1.21	27.50[a]	68.75	*B*	
March 21...	*PP*–2321	200	1.21	21.00	65.62	*B*	65.00
March 17...	*PP*–2307	200	1.21	21.50	67.19	*C*	
March 18...	*PP*–2308	200	1.21	22.00	68.75	*C*	
March 25...	*PP*–2324	200	1.21	20.00	62.50	*C*	
March 21...	*PP*–2322	200	1.21	21.00	65.62	*C*	
March 25...	*PP*–2325	200	1.21	19.75	61.72	*C*	65.16

[a] Indicator spring 0.40 millimetres = 1 kilogram per square centimetre.

$P = (1.911A + 0.5B - 1.411C) - 9.287 = 73.72$ kilograms per square centimetre.

TABLE II.

Theoretical Maximum Pressure in Own Volume of Sample M–2303 of 60/40 Sodatol at Densities of Loading Varying from 1.50 to 1.80.

Density	Kilograms per square centimetre	Pounds per square inch
1.50	8294	117970
1.55	8570	121890
1.60	8846	125820
1.65	9123	129760
1.70	9399	133680
1.75	9676	137620
1.80	9952	141550

Sample *M–2304* of 50/50 amatol.
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1918	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Nov. 11....	*P–1674*[a]	200	1.30	23.50	73.44	*A*	
Nov. 22....	*P–1675*	200	1.30	29.25	73.12	*A*	73.28
Nov. 27....	*PP–2196*	200	1.30	29.50	73.75	*B*	
	2197	200	1.30	27.00	67.50	*B*	
	2198	200	1.30	28.75	71.88	*B*	
	2199	200	1.30	28.25	70.62	*B*	70.90
	2200	200	1.30	26.75	66.88	*C*	
	2201	200	1.30	28.50	71.25	*C*	
	2202	200	1.30	28.75	71.88	*C*	70.00

[a] Indicator spring 0.32=1 kilogram per square centimetre.

$P = 1.911A + 0.5B - 1.411C = 76.72$ kilograms per square centimetre.

TABLE III.

Theoretical Maximum Pressure in Own Volume of Sample M–2304 of 50/50 Amatol at Densities of Loading Varying from 1.30 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
1.30	7480	106390
1.35	7768	110490
1.40	8056	114580
1.45	8343	118660
1.50	8631	122760
1.55	8919	126860
1.60	9207	130960

Sample *M*–2305 of TNA.
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Feb. 26.....	*P*–1704	200	0.87	31.00	77.50	*A*	
Feb. 26.....	*P*–1705	200	.87	29.50	73.75	*A*	75.63
Feb. 21.....	*PP*–2274	200	.87	27.50	68.75	*B*	
	2272	200	.87	26.50	66.25[a]	*B*	
	2273	200	.87	28.50	71.25	*B*	70.00
	2275	200	.87	28.00	70.00	*C*	
	2276	200	.87	27.25	68.12	*C*	69.06

[a] Omitted from average. No apparent reason for low result.

$$P = 1.911A + 0.5B - 1.411C = 82.09 \text{ kilograms per square centimetre.}$$

TABLE IV.

Theoretical Maximum Pressure of Sample M–2305 of TNA at Densities of Loading Varying from 0.80 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	4925	70050
.85	5233	74430
.90	5541	78810
.95	5849	83090
1.00	6159	87570
1.05	6465	91950
1.10	6772	96320
1.15	7080	100700
1.20	7388	105080
1.25	7696	109460
1.30	8004	113840
1.35	8312	118220
1.40	8619	122590
1.45	8927	126970
1.50	9235	131350
1.55	9534	135730
1.60	9851	140110

Sample *M*–2307 of ammonium picrate.
Fired at atmospheric pressure in gauge.
24 gram booster of picric acid (*M*–2308–*A*).
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
March 20...	*P*–1730	200	0.82	31.25	78.12	*A*	
March 20...	*P*–1731	200	.82	29.00	72.50[a]	*A*	
March 21...	*P*–1732	200	.82	32.00	80.00	*A*	79.06
March 21...	*PP*–2316	200	.82	30.75	76.88[b]	*B*	
March 21...	*PP*–2317	200	.82	28.50	71.25	*B*	
March 21...	*PP*–2318	200	.82	29.00	72.50	*B*	71.88
March 21...	*PP*–2319	200	.82	28.50	71.25	*C*	
March 23...	*PP*–2323	200	.82	27.50	68.75	*C*	70.00

[a] No apparent reason for low result.
[b] No apparent reason for high result.

$P = (1.911A + 0.5B - 1.411C) - 8.642 = 79.61$ kilograms per square centimetre.

TABLE V.

Theoretical Maximum Pressure of Sample M–2307 of Ammonium Picrate at Densities of Loading Varying from 0.80 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	4777	67940
.85	5075	72180
.90	5374	76440
.95	5672	80670
1.00	5971	84930
1.05	6269	89170
1.10	6568	93420
1.15	6866	97660
1.20	7165	101910
1.25	7463	106150
1.30	7762	110400
1.35	8061	114650
1.40	8359	118890
1.45	8658	123140
1.50	8956	127380
1.55	9255	131640
1.60	9553	135870

Sample *M*–2308–*A* of picric acid.
Indicator spring 0.60 millimetre = 1 kilogram per square centimetre.

Date	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Dec. 14, 1918	*P*–1692	200	0.94	25.25[a]	63.12	*A*	
Feb. 10, 1919	*P*–1698	200	.94	39.25	65.42	*A*	64.27
Dec. 13, 1918	*PP*–2235	200	.94	35.75	59.58	*B*	
Feb. 12, 1919	*PP*–2261	200	.94	36.50	60.83	*B*	
Dec. 13, 1918	*PP*–2234	200	.94	34.00	56.67	*B*	59.03
Dec. 13, 1918	*PP*–2229	200	.94	21.75[a]	54.38	*C*	
Dec. 13, 1918	*PP*–2230	200	.94	37.25	62.08	*C*	
Dec. 13, 1918	*PP*–2232	200	.94	25.25	58.75	*C*	
Dec. 13, 1918	*PP*–2233	200	.94	31.50	52.50	*C*	56.93

[a] Indicator spring 0.40 millimetres = 1 kilogram per square centimetre.

$P = 1.911A + 0.5B - 1.411C = 72.02$ kilograms per square centimetre.

TABLE VI.

Theoretical Maximum Pressure of Sample M-2308—A of Picric Acid at Densities of Loading Varying from 0.80 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	4321	61460
.85	4591	65300
.90	4861	69140
.95	5131	72980
1.00	5402	76830
1.05	5672	80670
1.10	5942	84510
1.15	6212	88350
1.20	6482	92190
1.25	6752	96040
1.30	7022	99880
1.35	7292	103720
1.40	7562	107560
1.45	7832	111400
1.50	8102	115240
1.55	8372	119080
1.60	8642	122920

Sample *M*-2320 of grade I TNT.
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1918	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Nov. 21....	*P*-1673	200	0.91	20.50[a]	64.06	*A*	
Dec. 5.....	*P*-1685	200	.91	38.00[b]	63.33	*A*	
Dec. 5.....	*P*-1686	200	.91	37.25[b]	62.08	*A*	63.16
Nov. 29....	*PP*-2207	200	.91	25.75	64.38	*B*	
Nov. 29....	*PP*-2208	200	.91	24.50	61.25	*B*	62.82
Nov. 29....	*PP*-2205	200	.91	24.75	61.88	*C*	
Nov. 29....	*PP*-2206	200	.91	24.50	61.25	*C*	61.56

[a] Indicator spring 0.32 millimetres = 1 kilogram per square centimetre.
[b] Indicator spring 0.60 millimetres = 1 kilogram per square centimetre.

$P = 1.911A + 0.5B - 1.411C = 65.58$ kilograms per square centimetre.

TABLE VII.

Theoretical Maximum Pressure of Sample M–2320 of Grade I TNT at Densities of Loading Varying from 0.80 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	3935	55970
.85	4181	59470
.90	4427	62970
.95	4673	66470
1.00	4919	69960
1.05	5164	73450
1.10	5410	76950
1.15	5656	80450
1.20	5902	83950
1.25	6148	87440
1.30	6394	90940
1.35	6640	94440
1.40	6886	97940
1.45	7132	101440
1.50	7378	104940
1.55	7624	108440
1.60	7870	111940

Sample *M*–2321 of grade II TNT.
Indicator spring 0.60 millimetre = 1 kilogram per square centimetre.

Date 1918	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Dec. 3.....	*P*–1680	200	0.91	38.00	63.33	*A*	
	P–1682	200	.91	39.75	66.25	*A*	64.79
	PP–2209	200	.91	35.75	59.59	*B*	
	PP–2210	200	.91	35.50	59.17	*B*	59.38
	PP–2211	200	.91	35.25	58.75	*C*	
	PP–2212	200	.91	35.50	59.17	*C*	58.96

$P = 1.911A + 0.5B - 1.411C = 70.31$ kilograms per square centimetre.

TABLE VIII.

Theoretical Maximum Pressure of Sample M–2321 of Grade II TNT at Densities of Loading Varying from 0.80 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	4219	60010
.85	4482	63750
.90	4746	67500
.95	5010	71260
1.00	5273	75000
1.05	5537	78750
1.10	5801	82510
1.15	6064	86250
1.20	6328	90000
1.25	6592	93760
1.30	6855	97500
1.35	7119	100250
1.40	7383	105010
1.45	7646	108750
1.50	7910	112510
1.55	8174	116260
1.60	8437	120000

Sample *M*–2328 of grade III TNT.
Indicator spring 0.60 millimetre = 1 kilogram per square centimetre.

Date 1918	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Dec. 4.....	*P*–1683	200	0.91	38.00	63.33	*A*	
	P–1684	200	.91	36.50	60.83	*A*	62.08
	PP–2213	200	.91	38.25	63.75	*B*	
	PP–2215	200	.91	37.25	62.08	*B*	
Dec. 5.....	*PP*–2219	200	.91	34.25	57.08	*B*	
Dec. 5.....	*PP*–2220	200	.91	35.25	58.75	*B*	60.42
Dec. 5.....	*PP*–2216	200	.91	35.75	59.58	*C*	
Dec. 5.....	*PP*–2218	200	.91	35.25	58.75	*C*	59.16

$P = 1.911A + 0.5B - 1.411C = 65.37$ kilograms per square centimetre.

TABLE IX.

Theoretical Maximum Pressure of Sample M–2328 of Grade III TNT at Densities of Loading Varying from 0.80 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	3922	55780
.85	4167	59270
.90	4412	62750
.95	4658	66250
1.00	4903	69740
1.05	5148	73220
1.10	5393	76710
1.15	5638	80190
1.20	5883	83680
1.25	6128	87160
1.30	6374	90660
1.35	6619	94140
1.40	6864	97630
1.45	7109	101110
1.50	7354	104600
1.55	7599	108080
1.60	7844	111570

Sample *M*–2325 of trinitroxylene.
24 gram booster of tetryl (*M*–2326).
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Mar. 13. . . .	*P*–1719	200	0.82	23.50	58.75	*A*	
	P–1720	200	.82	22.75	56.88	*A*	57.82
	PP–2299	200	.82	22.00	55.00	*B*	
	PP–2300	200	.82	22.25	55.62	*B*	55.31
	PP–2297	200	.82	21.25	53.12	*C*	
	PP–2298	200	.82	21.50	53.75	*C*	53.44

$P = (1.911A + 0.5B - 1.411C) - 9.287 = 53.46$ kilograms per square centimetre.

TABLE X.

Theoretical Maximum Pressure of Sample M–2325 of Trinitroxylene at Densities of Loading Varying from 0.80 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	3208	45630
.85	3408	48470
.90	3609	51330
.95	3809	54180
1.00	4010	57040
1.05	4210	59880
1.10	4410	62720
1.15	4611	65580
1.20	4811	68430
1.25	5012	71290
1.30	5212	74130
1.35	5413	76990
1.40	5613	79830
1.45	5814	82690
1.50	6014	85540
1.55	6215	88390
1.60	6415	91240

Sample *M*–2326 of tetryl.
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Feb. 26.....	*P*–1706	200	0.99	28.75	71.88	*A*	
Feb. 26.....	*P*–1707	200	.99	26.75	66.88	*A*	
Feb. 27.....	*P*–1708	200	.99	31.25	78.12	*A*	
Feb. 27.....	*P*–1709	200	.99	27.50	68.75	*A*	71.41
Feb. 21.....	*PP*–2269	200	.99	28.50	71.25	*B*	
Feb. 21.....	*PP*–2271	200	.99	27.50	68.75	*B*	70.00
Feb. 20.....	*PP*–2266	200	.99	27.00	67.50	*C*	
Feb. 20.....	*PP*–2267	200	.99	26.50	66.25	*C*	
Feb. 21.....	*PP*–2270	200	.99	26.50	66.25	*C*	66.67

$P = 1.911A + 0.5B - 1.411C = 77.39$ kilograms per square centimetre.

TABLE XI.

Theoretical Maximum Pressure of Sample M–2326 of Tetryl at Densities of Loading Varying from 0.80 to 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	4643	66040
.85	4934	70180
.90	5224	74300
.95	5514	78430
1.00	5804	82550
1.05	6094	86680
1.10	6385	90820
1.15	6675	94940
1.20	6965	99060
1.25	7255	103190
1.30	7546	107330
1.35	7836	111450
1.40	8126	115580
1.45	8416	119700
1.50	8706	123830
1.55	9196	127960
1.60	9486	132090

Sample *M*–2336 of hexanitrodiphenylamine.
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
Feb. 14.....	*P*–1702	200	0.81	28.75	71.88	*A*	
	P–1703	200	.81	28.50	71.25	*A*	71.57
	PP–2262	200	.81	23.75	59.38	*B*	
Feb. 18.....	*PP*–2263	200	.81	24.50	61.25	*B*	60.32
	PP–2264	200	.81	23.50	58.75	*C*	
	PP–2265	200	.81	24.25	60.62	*C*	59.69

$P = 1.911A + 0.5B - 1.411C = 82.71$ kilograms per square centimetre.

TABLE XII.

Theoretical Maximum Pressure of Sample M–2336 of Hexanitrodiphenylamine at Densities of Loading Varying from 0.80 to 160.

Density	Kilograms per square centimetre	Pounds per square inch
.80	4963	70590
.85	5273	75000
.90	5583	79410
.95	5893	83820
1.00	6203	88230
1.05	6513	92640
1.10	6824	97060
1.15	7134	101470
1.20	7444	105880
1.25	7754	110290
1.30	8064	114700
1.35	8374	119110
1.40	8685	123530
1.45	8995	127940
1.50	9305	132350
1.55	9615	136760
1.60	9925	141170

Sample *M*–2344 of trinitronaphthalene.
24 gram booster of tetryl (*M*–2326).
Indicator spring 0.40 millimetre = 1 kilogram per square centimetre.

Date 1919	Test No.	Charge	Specific gravity	Height of curve	Pressure per square centimetre	Cooling surface	Average pressure per square centimetre
		Grams		*Millimetres*	*Kilograms*		*Kilograms*
March 10...	*P*–1716	200	0.99	22.25[a]	69.53[b]	*A*	
March 11...	*P*–1717	200	.99	25.75	64.38	*A*	
	P–1718	200	.99	26.00	65.00	*A*	64.69
	PP–2292	200	.99	23.00	57.50[c]	*B*	
	PP–2293	200	.99	24.50	61.25	*B*	
	PP–2294	200	.99	25.25	63.12	*B*	62.19
March 12...	*PP*–2295	200	.99	25.25	63.12	*C*	
	PP–2296	200	.99	24.00	60.00	*C*	61.56

[a] Indicator spring 0.32 millimetres = 1 kilogram per square centimetre.
[b] No apparent reason for high result.
[c] No apparent reason for low result.

$P = 1.911A + 0.5B - 1.411C - 9.287 = 58.57$ kilograms per square centimetre.

TABLE XIII.

Theoretical Maximum Pressure of Sample M–2344 of Trinitronaphthalene at Densities of Loading Varying from 0.80 *to* 1.60.

Density	Kilograms per square centimetre	Pounds per square inch
.80	3514	49980
.85	3734	53110
.90	3953	56220
.95	4173	59350
1.00	4393	62480
1.05	4612	65600
1.10	4832	68730
1.15	5052	71860
1.20	5271	74970
1.25	5491	78100
1.30	5711	81230
1.35	5930	84340
1.40	6150	87470
1.45	6369	90590
1.50	6589	93720
1.55	6809	96850
1.60	7029	99980

TABLE XIV.

Recapitulation of Theoretical Maximum Pressure in Own Volume in Pounds per Square Inch.

Density	80/20 Amatol *M*–2302	60/40 Sodatol *M*–2303	50/50 Amatol *M*–2304	TNA *M*–2305	Ammonium picrate *M*–2307	Picric Acid *M*–2308	TNT Grade I *M*–2320	TNT Grade II *M*–2321	TNT Grade III *M*–2328	Trinitroxylene *M*–2325	Tetryl *M*–2326	Hexanitrodiphenylamine *M*–2336	T. N. N. *M*–2344
0.80	.....	.....	.....	70070	67940	61460	55970	60010	55780	45630	66040	70590	49980
.85	.....	.....	.....	74430	72180	65300	59470	63750	59270	48470	70180	75000	53110
.90	.....	.....	.....	78810	76440	69140	62970	67500	62750	51320	74300	79410	56220
.95	.....	.....	.....	83090	80670	72980	66470	71260	66250	54180	78430	83820	59350
1.00	.....	.....	.....	87570	84930	76830	69960	75000	69740	57040	82550	88230	62480
1.05	.....	.....	.....	91950	89770	80670	73450	78750	73220	59880	86680	92640	65600
1.10	.....	.....	.....	96320	93420	84510	76950	82510	76710	62720	90820	97060	68730
1.15	.....	.....	.....	100700	97660	88350	80450	86250	80190	65580	94940	101470	71860
1.20	.....	.....	.....	105080	101910	92190	83950	90000	83680	68430	99060	105880	74970
1.25	.....	.....	.....	109460	106150	96040	87440	93760	87160	71290	103190	110290	78100
1.30	126860	.....	106390	113840	110400	99880	90940	97500	90660	74130	107330	114700	81230
1.35	131340	.....	110490	118220	114650	103720	94440	101250	94140	76990	111450	119110	84340
1.40	136010	.....	114580	122590	118890	107560	97940	105010	97630	79830	115580	123530	87470
1.45	141490	.....	118660	126970	123140	111400	101440	108750	101110	82690	119700	127940	90590
1.50	146390	117970	122760	131350	127380	115240	104940	112510	104600	85540	123830	132350	93720
1.55	151270	121890	126860	135730	131640	119080	108440	116260	108080	88390	127960	136760	96850
1.60	156150	125820	130960	140110	135870	122920	111940	120000	111570	91240	132090	141170	99980
1.65	.....	129760	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1.70	.....	133680	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1.75	.....	137620	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1.80	.....	141550	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE XV.

Recapitulation of Theoretical Maximum Pressure in Own Volume in Kilograms per Square Centimetre.

Density	80/20 Amatol *M*–2302	60/40 Sodatol *M*–2303	50/50 Amatol *M*–2304	TNA *M*–2305	Ammonium picrate *M*–2307	Picric Acid *M*–2308	TNT Grade I *M*–2320	TNT Grade II *M*–2321	TNT Grade III *M*–2328	Trinitroxylene *M*–2325	Tetryl *M*–2326	Hexanitrodiphenylamine *M*–2336	T. N. N. *M*–2344
0.80	.....	.....	.....	4925	4777	4321	3935	4219	3922	3208	4643	4963	3514
.85	.....	.....	.....	5233	5075	4591	4181	4482	4167	3408	4934	5273	3734
.90	.....	.....	.....	5541	5374	4861	4427	4746	4412	3609	5224	5583	3953
.95	.....	.....	.....	5849	5672	5131	4673	5010	4658	3809	5514	5893	4173
1.00	.....	.....	.....	6157	5971	5402	4919	5273	4903	4010	5804	6203	4393
1.05	.....	.....	.....	6465	6269	5672	5164	5537	5148	4210	6094	6513	4612
1.10	.....	.....	.....	6772	6568	5942	5410	5801	5393	4410	6385	6824	4832
1.15	.....	.....	.....	7080	6866	6212	5656	6064	5638	4611	6675	7134	5052
1.20	.....	.....	.....	7388	7165	6482	5902	6328	5883	4811	6965	7444	5271
1.25	.....	.....	.....	7696	7463	6752	6148	6592	6128	5012	7255	7754	5491
1.30	8919	.....	7480	8004	7762	7022	6394	6855	6374	5212	7546	8064	5711
1.35	9262	.....	7768	8312	8061	7292	6640	7119	6619	5413	7836	8374	5930
1.40	9605	.....	8056	8619	8359	7562	6886	7383	6864	5613	8126	8685	6150
1.45	9948	.....	8343	8927	8658	7832	7132	7646	7109	5814	8416	8995	6369
1.50	10292	8294	8631	9235	8956	8102	7378	7910	7354	6014	8706	9305	6589
1.55	10635	8570	8919	9543	9255	8372	7624	8174	7599	6215	9196	9615	6809
1.60	10978	8846	9207	9851	9553	8642	7870	8437	7844	6415	9486	9925	7029
1.65	.....	9123	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1.70	.....	9399	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1.75	.....	9676	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1.80	.....	9952	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

No comparison is made between the strength of these explosives as shown by the theoretical maximum pressure as the different explosives are not all used at the same density. However, Tables XIV and XV furnish the data so that an explosive at one density may be compared with any other explosive at a selected density.

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The December, 1919, Number of the Transactions of the Faraday Society is devoted to a discussion of "The Present Position of the Theory of Ionization," to which Arrhenius contributes a paper on the evidence in favor of the theory. N. R. Dhar discusses Snethlage's hypothesis of the condition of dissolved electrolytes and finds it wanting. The fifteen papers, with the accompanying discussion, form a useful contribution to the study of Arrhenius' theory.

G. F. S.

Oil and Gas Prospects in East-central New Mexico. (*U. S. Geological Survey, Press Bulletin* No. 441.)—The geologic structure of parts of New Mexico has been under investigation during the last four years by N. H. Darton, a geologist of the United States Geological Survey, Department of the Interior, who has discovered in the beds of rock many domes and arches that may be reservoirs of oil or gas if these substances are present in the regions examined. These flexed beds are parts of geologic formations that produce oil in Wyoming, Oklahoma, Kansas, and Texas, but in New Mexico little evidence of the presence of oil and gas in them has yet been found. A small amount of oil at Dayton and a few seeps and some traces of oil reported in water wells at several other places are the only favorable indications so far reported. Only a few deep wells have been bored in New Mexico, however, and these are in places where the structure is not favorable for the occurrence of oil or gas, or the wells were not drilled deep enough to make them satisfactory tests. Much of the geologic guidance used in locating the wells drilled has come from incompetent "experts," the presence of one "dome," for ex-

ample, having been deduced from haphazard readings of dip taken on layers of cross-bedded sandstone. One probably hopeless project is a deep hole in the middle of Tularosa Desert, where there are no rock outcrops to indicate the structure. In some of the hectic literature written to promote the sale of oil stock the chief geologist of the United States Geological Survey is falsely quoted as authority for the statement that New Mexico would develop one of the biggest oil fields on this continent.

Localities of Domes and Arches.—The general structure of east-central New Mexico is that of an eastward-dipping monocline, but there are local reversals of dip due to domes and arches, or anticlines, some of which are rather prominent. Only a few of the areas where these structural features appear to merit the attention of the geologist and driller can be mentioned here. In Guadalupe County, for example, the apex of one of the most clearly marked domes is in the west-central part of T. 11 N., R. 19 E. The uplifted beds, which are 2500 feet thick, are of Permian and Pennsylvanian age, and the Pennsylvanian beds lie on granite at a vertical depth of 2000 feet or more. On Pintada Creek, in the centre of T. 8 N., R. 19 E., there is a smaller dome involving the same strata, and a slightly less pronounced dome is indicated in the same canyon a few miles above Pintada post office. There are several broad, low arches in the strata in the northeast corner of this county and in adjoining parts of San Miguel, the next county to the north. In Quay County a broad, low anticline in the "red beds" passes a short distance east of Tucumcari and extends for some distance north and south of the Rock Island Railroad. In De Baca County the strata dip nearly due east in general, but a few local reversals of dip suggest that minor domes or arches may be found when a detailed survey is made. Lincoln County is traversed by a broad anticline that lies east of the Sierra Blanca structural basin and passes near Lincoln. In the western part of Lincoln County there are several domes that appear to be favorable for the storage of oil, although there is no visible evidence that they contain oil. They are in T. 6 S., R. 9 E., in the northeastern part of T. 9 S., R. 8 E., and in the centre of T. 5 S., R. 12 E. In the eastern part of Socorro County, three miles northeast of the Carthage coal mines, there is a notable elongated dome which brings up the Mesaverde coal measures; at Prairie Springs there is a dome in the limestones of Permian age; and in the centre of T. 2 S., R. 4 E., there is a dome in the Abo red beds. The plunging anticline at the north end of the Oscura Mountain uplift is also in the eastern part of this county.

Wells Should be Sunk Deep.—All test wells sunk in this region should be carried entirely through the sedimentary series, which in the domes and anticlines mentioned is from 2000 to 3000 feet thick and at intervals from top to bottom contains coarse sands, some of which may be oil burning.

ON THE RESISTANCE OF DUCTILE MATERIALS TO COMBINED STRESSES IN TWO OR THREE DIRECTIONS PERPENDICULAR TO ONE ANOTHER.*

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If two structural steel plates are pulled, the one by a simple tension in one direction only, the other by equal tensions in two directions perpendicular to one another, then the question arises: in which case, if the unit stresses are the same, is there the greater safety? For example, if 14,000 lbs. per. sq. in. is a safe working stress in the case of a simple tension, what would be the safe working stress in the case of equal tensions in the two perpendicular directions? Different answers to this question and to the general question of the resistance of materials to combined stresses are given by several different theories or assumptions, which in the course of time have been proposed as bases of design.

Rankine's theory, the maximum stress theory, states that the tendency to failure is measured by the greatest tensile or compressive unit stress; that is, with 14,000 lbs. per sq. in. as a working stress in simple tension, the same working unit stress would be used in biaxial tension. *Saint-Venant's maximum strain theory* measures the tendency to rupture by the greatest unit-elongation or unit-shortening, as computed by the formulas applying to deformations below the elastic limit (see the equations given later). On account of the lateral contraction effect, measured by the so-called Poisson's ratio of lateral contraction, which for steel is equal to about 0.3, the unit-elongation caused by equal tensions in two directions will be about 30 per cent. less than (or 0.7 of) the greatest unit-elongation caused by the same stress applied as a simple tension; or, by Saint-Venant's theory the working stress in the case of biaxial equal tensions, corresponding to 14,000 lbs. per sq. in. in simple tension, should be 14,000/.7 = 20,000 lbs. per sq. in. A third theory, the *maximum shear theory*, originally proposed by Coulomb (1773), and adopted by

* Communicated by the Author.

Guest (1900) and others, states that failure occurs when the greatest shearing unit stress exceeds a certain limit. In the case of biaxial tension, the maximum shearing unit stress occurs in planes making angles of 45° with the plane of the tensions, and it is equal to one-half the greatest tensile unit stress (see more complete formulas given below). Or, in the example considered, a tensile stress of 14,000 lbs. per sq. in. would give the same shear, 7000 lbs. per sq. in., whether it is applied as a simple or as a biaxial tension. That is, a working stress of 14,000 lbs. per sq. in. in simple tension would lead to the same working stress for the case of biaxial tensions. Other theories have also been proposed; one, to which particular attention will be given in this discussion, was indicated by A. J. Becker[1] as a result of a recent experimental investigation. This theory leads in the above example to a working stress which would be between the extreme values, 14,000 lbs. per sq. in. and 20,000 lbs. per sq. in., as found by the preceding theories.

The question of the resistance to compound stress is of well recognized importance. Biaxial stresses occur in boilers, which must resist circumferential as well as longitudinal stresses; in plates which are supported all around the edge and are bent by a pressure from the side; in shafts which are bent and twisted at the same time. For that matter, any case of pure shear is an example of biaxial stress, because a shear is actually a tension combined with an equal compression in directions making 45° angles with the shearing stresses. Compressions in three direc-

[1] A. J. Becker: The Strength and Stiffness of Steel under Biaxial Loading, *Univ. of Illinois, Eng. Exp. Sta. Bull. 85*, 1916. This bulletin, besides reporting the author's tests, discusses the general problem of the resistance to combined stresses, and gives a bibliography. Among the preceding works should be mentioned: O. Mohr's discussion, "Welche Umstände bedingen die Elastizitätsgrenze und den Bruch eines Materials?" *Zeitschr. des Vereins Deutscher Ingenieure*, 1900, p. 1524, p. 1572 (also in his Abhandlungen auf dem Gebiete der technischen Mechanik, 2 ed., 1914, pp. 192–235); works by J. Guest (*Phil. Magazine*, July, 1900); W. Scoble (*Phil. Magazine*, 1906, p. 553); C. A. Smith (*Engineering*, July 10, 1908, March 5, August 20, December 24, 1909); L. B. Turner (*Engineering*, February 5, 12, 1909); W. Mason (*Engineering*, December 24, 1909); Cook and Robertson (*Engineering*, December 15, 1911); and P. W. Bridgman, (*Phil. Magazine*, July, 1912); also works by Föppl, Voight, and Kármán. A general discussion of the causes of failure is found, for example, in J. E. Boyd, Strength of Materials, 2 ed., 1917, Chapter 17.

tions occur in hooped guns and in other thick cylinders, and in spiral reinforced concrete columns; in these cases the increase of strength, when compressions act in three directions, is utilized.

The test data now at hand, although extensive, are limited when compared with the variety of stress combinations which would have to be tried in order to find the complete law of strength and failure even for one single material. Some of the combinations, for example, three equal tensions, are difficult to produce. The field best covered by experiment, as far as ductile materials are concerned, is that of biaxial stresses or plane stresses, such as occur in a plate resisting stresses in its own plane only (see the works quoted in the previous footnote). The result of the incompleteness of test data is that we are, as yet, in the stage of partially or approximately verified hypotheses. Further data are needed to verify or overthrow the working hypothesis which agrees best at present with experimental results, and which may have been selected, in view of the fact that designs must be made, as the best present choice; such a hypothesis may be satisfactory as an approximation and as the best choice that can be made until further information is available.

It is natural to select the simplest hypothesis which can be made to agree approximately with available data. Thus, when only few data were known *Rankine's maximum stress theory* was acceptable as the preferred hypothesis. When the importance of the difference which exists between the deformations caused by simple stresses and those caused by compound stresses of the same intensity was realized, then *Saint-Venant's maximum strain theory* gained ground, and for quite a long time it was used extensively as a basis of design, particularly in Europe. But later the experiments made by Guest and others, from about 1900 on (see previous footnote), showed a better agreement with the *maximum shear theory* (*Coulomb's hypothesis*, 1773, *Guest's law*, 1900) than with either the maximum stress or the maximum strain theories, and thus it was finally experimentally established that if one of the three hypotheses mentioned is to be selected as applying to the biaxial (plane) state of stresses in ductile materials, then Guest's law is preferable. It appears, however, that at different combinations of the stresses different laws might apply. In fact, A. J. Becker found, as a result of his above-quoted

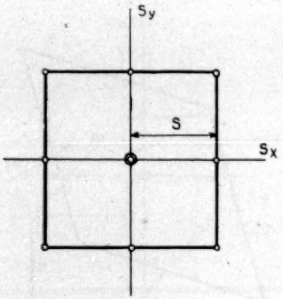
tests (1916), that with some combinations of biaxial stresses failure occurred at an almost constant maximum elongation, while with other combinations failure occurred at an almost constant maximum shear. This result led Becker to a *maximum shear and maximum strain theory*, according to which failure begins when either the shear or the strain reaches limiting values. He also found, upon a closer examination, that this conclusion was supported by the data from previous tests. Later experimental work (which will be mentioned presently) has pointed in the same direction.

If two different laws govern the failure, then it becomes important to know the field within which each law applies. A clear representation of the different laws is obtained most simply by adopting some *graphical representation of the state of stresses.* In the general case there are, at a given point, stresses in all directions; among these there are the three "*principal directions,*" perpendicular to one another, in which there are no shears. The normal stresses (tensions or compressions) in these directions are called the "*principal stresses.*" The principal stresses and their directions determine completely the state of stresses and of deformations at the point. One of the principal stresses is the greatest, another the smallest (largest negative) of all the stresses at the point. The maximum shear occurs in the two planes making 45° with the directions of the largest and of the smallest principal stress. The maximum shear is one-half the difference between the largest and the smallest principal stress. In the plane (biaxial) state of stresses the two principal directions are in the plane of the stresses, the third is perpendicular to the plane, and the principal stress in that direction is equal to zero.

If we assume that the material is isotropic at the point considered, that is, has the same qualities in all directions, thereby excluding such materials as wood, and to some extent wrought iron, then the directions of the principal stresses will not matter as far as the strength is concerned, and the important data will be the values of the three principal stresses, S_x, S_y, and S_z; they will, as stated before, determine the greatest shears and the strains. By laying off S_x, S_y, and S_z as rectangular coördinates a point (S_x, S_y, S_z) will be determined which represents the state of stresses. And each possible state of stresses defines such a point, which, for the sake of brevity, we shall call a stress point.

The condition of resistance to compound stress may then always be stated by requiring the stress point (S_x, S_y, S_s) *to be within or on the surface of a certain solid.* The surface of the solid determines the limiting stresses, and therefore the problem of resistance to combined stresses may be stated as the problem of determining this solid. If only plane states of stresses are considered, then the corresponding requirement is that the stress point (S_x, S_y), laid off in rectangular coördinates in the plane, must be within or on the boundary of a certain closed area; the boundary—a curve or a polygon—defines the stress limits. The experimental

FIG. 1.



Maximum stress.

proof that a certain boundary is the correct one is that the stress points, found by plotting the limiting stresses as determined from experiments, are on or near this boundary.

We shall begin by applying this graphical representation to the various hypotheses as referring to the plane state of stresses only. With limiting tensions and compressions $\pm S$ the stress field corresponding to *Rankine's maximum stress theory* is evidently a square (Fig. 1),[2] bounded by the lines $S_x = \pm S$, and $S_y = \pm S$. The corner $(+S, -S)$ represents a pure shear in the directions of the diagonals; but tests show that the limiting shearing stress is in reality less than the limiting simple tension; or, the stress point $(+S_s, -S_s)$ representing the actual limiting pure shear,

[2] The diagrams shown in Figs. 1 to 4 are given in Becker's previously quoted work.

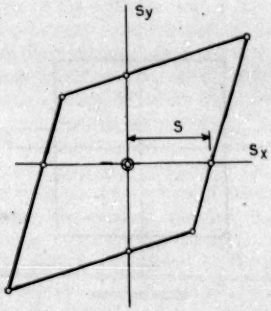
S_x, is at some distance inside the corner $(+S, -S)$. This proves that Rankine's theory can not be correct.

By *Saint-Venant's maximum strain theory* the tendency or the nearness to rupture is measured by the strain at stresses below the elastic limit. The unit elongation in the x-direction is given by the expression

$$\epsilon_x = (1/E)\,(S_x - KS_y)$$

where E = modulus of elasticity, K = Poisson's ratio of lateral contraction (for steel about 0.3). If $S_x > S_y$, then ϵ_x is the largest elongation at the point. As E is a constant, it follows that also

FIG. 2.



Maximum strain.

the quantity $E\epsilon_x = S_x - KS_y$ will measure the tendency to rupture. Saint-Venant's hypothesis states that $S_x - KS_y$ measures the tendency to rupture even when the elastic limit has been exceeded. When $\pm S$ = limiting simple tension or compression, then the limiting biaxial stresses, S_x, S_y, are consequently defined by the equations

$$S_x - KS_y = \pm S \text{ and } S_y - KS_x = \pm S$$

defining four straight lines, enclosing a rhombus (Fig. 2). In the figure $K = 0.3$. Two of the vertices are $S_x = S_y = S/(1-K) = 1.43\ S$, corresponding to equal tensions, and $S_x = -S_y = S/(1+K) = 0.77$, corresponding to equal but opposite stresses, that is, pure shear in the 45°-directions. The stresses corresponding to both of these vertices are higher than the values found by

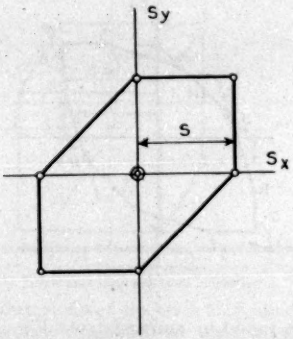
tests[3]; that is, the stress points representing the state of biaxial equal tensions and the state of pure shear are at some distance inside these vertices. Therefore, the working stresses derived from this hypothesis are not sufficiently safe.

The *maximum shear theory, Guest's law,* is represented in Fig. 3. In the plane state of stresses the principal stresses are S_x, S_y, and o; that is, when $S_x > S_y > o$, then the maximum shear is $\frac{1}{2}(S_x - o) = S_x/2$, and when $S_x > o > S_y$ then the shear is $\frac{1}{2}(S_x - S_y)$. That is, the limiting stresses are defined by

$$S_x = \pm S,\ S_y = \pm S,\ S_x - S_y = \pm S$$

giving the hexagon shown.. The state of pure shear is repre-

FIG. 3.



Maximum shear.

sented by the point $(S/2, -S/2)$, the state of biaxial equal tensions by the point (S, S). However, experimental data indicate that the limiting values, $S/2$ for pure shear, and S for biaxial equal tensions, as defined by these points, are too small.

Becker's "maximum shear and maximum strain theory" is represented in Fig. 4. It is readily seen that this diagram represents a solution which lies between those indicated in Fig. 2 and Fig. 3. As Fig. 2 gave too large values and Fig. 3 too small

[3] See the previously quoted papers by Guest, Scoble, Smith, Turner, Mason, etc.

values in the cases of pure shear and of biaxial equal tensions, it might be expected that some such diagram as Fig. 4 would give a satisfactory agreement with experimental data. Becker indicates that the limiting shear is approximately $S_s = 0.6\,S$. If this value is correct, and if the limiting elongation is S/E (E = modulus of elasticity), then the limiting stresses will be determined by

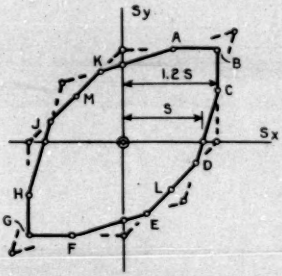
$$(1/2)S_x = \pm 0.6S, \quad (1/2)S_y = \pm 0.6S, \quad (1/2)(S_x - S_y) = \pm 0.6S,$$

and

$$S_x - KS_y = \pm S, \quad S_y - KS_x = \pm S.$$

These equations define the ten-sided polygon in Fig. 4, inside which the theory states that the stress point must remain. This

FIG. 4.

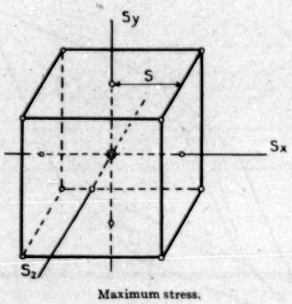


Maximum shear and maximum strain.

diagram may be found by starting from Fig. 2, cutting off the corners by superimposing a diagram which is similar to Fig. 2, but based on a limiting shear equal to 0.6 S instead of $S/2$. It is seen that the parts of the boundary ABC and FGH are governed by the shear in planes making 45°-angles with the xy-plane (compare Fig. 3), the parts DE and JK by shears in the two planes making 45° with the x-and y-axes, while the parts CD and KA are governed by the elongations (compare Fig. 2), EF and HJ by the shortenings. B represents the equal tensions $S_x = S_y = 1.2S$, while the points L and M define the limiting value of pure shear, $\pm S_x = \mp S_y = S_s = 0.6S$. While some individual tests have given lower values the ratio $S_s/S = 0.6$ was found to be justified by a rather large number of data taken from measurements of the

elastic limit and of the yield point; or, the stress points found by plotting the limiting stresses as determined by experiments, are on or near the boundary of the diagram in Fig. 4. A recent study by F. B. Seely and W. J. Putnam [4] of the relative values of elastic limits and yield points in shear and in simple tension for several grades of steel, led again to this same ratio, 0.6. That certain individual cases give slightly lower values is—as far as safety is concerned—counterbalanced by the fact that the ratio of ultimate shear to ultimate simple tension is rather larger than 0.6; it must be remembered that the "safety" is measured both relative to the ultimate stress and relative to the elastic limit. The value 0.6 and

FIG. 5.



Maximum stress.

the subsequent dimensions of Becker's diagram are, therefore, on the whole rather well justified by experimental data known at present.

At this place attention might be called to a method often used in Europe of indicating an "*equivalent stress*," sometimes called "ideal stress" [5] or "reduced stress" [6]; namely, a simple tension which is as "dangerous" or as "near failure" as the particular compound stress which is investigated. When, for example, S_z is positive and numerically greater than S_y, then

[4] F. B. Seely and W. J. Putnam: Relation between Elastic Strength of Steel in Tension, Compression, and Shear, *University of Illinois, Engineering Experiment Station Bull. 115*, 1919.

[5] A. Ostenfeld: Teknisk Elasticitetslære, 3 ed., 1916, p. 89.

[6] A. Föppl: Technische Mechanik, Vol. 3, ed. 1905, p. 63.

the equivalent stress, based on the diagram in Fig. 4, is seen to be the largest of the three values

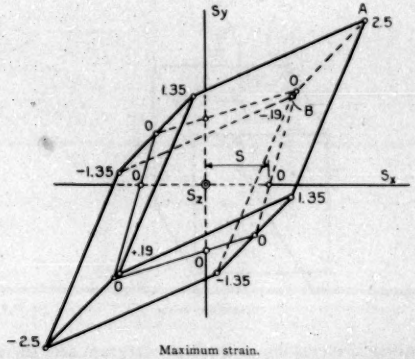
$$\frac{S_x}{1.2} \text{ corresponding to the side } BC \text{ (shear)}$$

$$S_x - KS_y, \text{ corresponding to the side } CD \text{ (elongation)}$$

$$\frac{S_x - S_y}{1.2} \text{ corresponding to the side } DE \text{ (shear)}$$

This "equivalent," "ideal," or "reduced" stress can be used as the measure of the tendency to failure. Similar expressions may be derived corresponding to the other sides of the polygon.

FIG. 6.



Maximum strain.

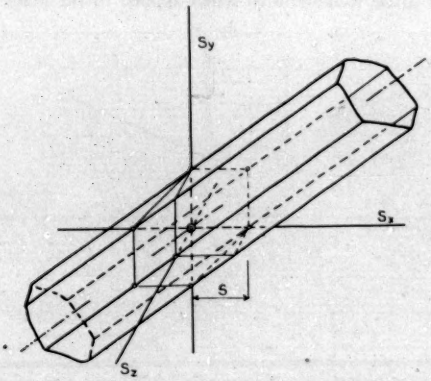
We shall now consider the *three-dimensional states of stresses*. That the solid representing the *maximum stress theory* is the cube shown in Fig. 5 is seen very readily. By the *maximum strain theory* the tendency to rupture is measured by such expressions as $E\epsilon_x = S_x - K(S_y + S_z)$, where ϵ_x is the elastic elongation in the x-direction. The limiting stresses are then defined by the relations

$$S_x - K(S_y + S_z) = \pm S, \; S_y - K(S_z + S_x) = \pm S, \; S_z - K(S_y + S_x) = \pm S$$

These six equations determine six planes, parallel in pairs, which enclose a skew parallelopiped, having its largest diagonal in the direction making equal angles with the x-, y-, and z-axes (the solid is shown in projection on the xy-plane in Fig. 6; the numbers indicate the values of S_z/S). This parallelopiped is then the

stress solid which represents Saint-Venant's maximum strain theory when applied to the general state of stresses in space. Its intersection with the xy-plane is the same as the diagram in Fig. 2. With $K = 0.3$, the vertex A representing three equal tensions has the coördinates $S_x = S_y = S_z = S/(1-2K) = 2.5S$; that is, $S = 16{,}000$ lbs. per sq. in. allowed in simple tension would correspond to 40,000 lbs. per sq. in. with three equal tensions (or

FIG. 7.



Maximum shear.

compressions). By solving three of the above equations the vertex B is found to have the coördinates:

$$S_x = S_y = \frac{1-K}{1-K-2K^2}\,S, \quad S_z = \frac{-1+3K}{1-K-2K^2}\,S$$

or, with $K = 0.3$,

$$S_x = S_y = 1.35\,S, \quad S_z = -.19\,S$$

When $S_x > S_y > S_z$ then the maximum shear, as stated before, is $S_s = \frac{1}{2}(S_x - S_z)$. A simple tension S gives a shear $\frac{1}{2}S$. Hence, the solid representing the *maximum shear theory* is bounded by the planes

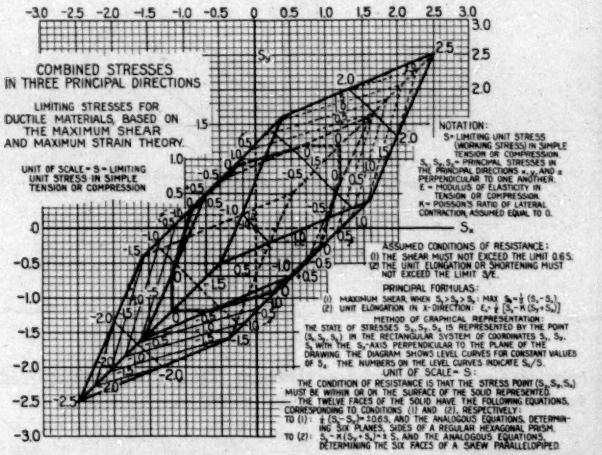
$$S_x - S_y = \pm S, \; S_y - S_z = \pm S, \; S_z - S_x = \pm S$$

Each of these six planes makes 45°-angles with two of the coördinate axes and is parallel to the third. The solid enclosed is a regular hexagonal prism (Fig. 7), the axis of which makes

equal angles with the three coördinate axes. The intersection with the xy-plane is the diagram in Fig. 3. That the prism is infinitely long is due to the fact that the shear remains small as long as the three principal stresses are almost equal; that is, the hypothesis allows unlimited almost equal stresses. That, for example, three exactly equal compressions (liquid pressure) would hardly break any material may be considered an established fact.

If the *maximum shear and maximum strain theory*, which was seen to be well-founded when applied to the plane state of

FIG. 8.


COMBINED STRESSES IN THREE PRINCIPAL DIRECTIONS
LIMITING STRESSES FOR DUCTILE MATERIALS, BASED ON THE MAXIMUM SHEAR AND MAXIMUM STRAIN THEORY.
UNIT OF SCALE = S = LIMITING UNIT STRESS IN SIMPLE TENSION OR COMPRESSION
NOTATION:
S = LIMITING UNIT STRESS (WORKING STRESS) IN SIMPLE TENSION OR COMPRESSION.
E = MODULUS OF ELASTICITY IN TENSION OR COMPRESSION.
K = POISSON'S RATIO OF LATERAL CONTRACTION, ASSUMED EQUAL TO 0.
ASSUMED CONDITIONS OF RESISTANCE:
(1) THE SHEAR MUST NOT EXCEED THE LIMIT 0.65.
(2) THE UNIT ELONGATION OR SHORTENING MUST NOT EXCEED THE LIMIT S/E.
PRINCIPAL FORMULAS:
METHOD OF GRAPHICAL REPRESENTATION:
UNIT OF SCALE = S:
THE CONDITION OF RESISTANCE IS THAT THE STRESS POINT MUST BE WITHIN OR ON THE SURFACE OF THE SOLID REPRESENTED. THE TWELVE FACES OF THE SOLID HAVE THE FOLLOWING EQUATIONS, CORRESPONDING TO CONDITIONS (1) AND (2), RESPECTIVELY:
TO (1):
TO (2):

stresses, can be applied also to the case of three-dimensional stresses, then the corresponding stress solid will be of particular interest. In fact, the particular purpose of this paper was to indicate this stress-solid. In analogy with the preceding cases the limiting stresses are defined by the following relations:

Corresponding to the shear condition:

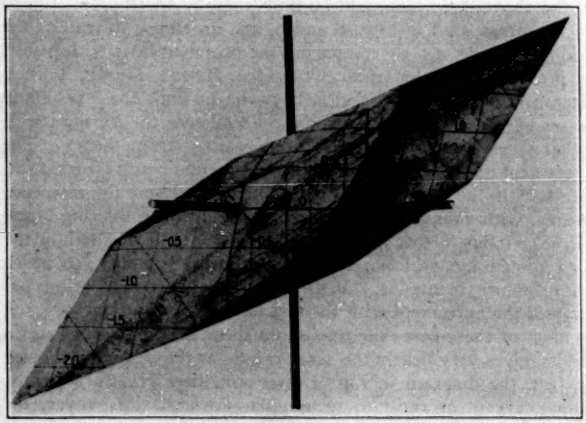
$$S_x - S_y = \pm 1.2\,S, \quad S_y - S_z = \pm 1.2\,S, \quad S_z - S_x = \pm 1.2\,S \ldots\ldots\ldots \quad (1)$$

and corresponding to the strain condition:

$$S_x - K(S_y + S_z) = \pm S; \quad S_y - K(S_x + S_z) = \pm S,$$
$$S_z - K(S_x + S_y) = \pm S \ldots\ldots\ldots\ldots \quad (2)$$

These twelve planes enclose a twelve-faced polyhedron, the projection of which on the xy-plane has been constructed in Fig. 8. It is determined by the intersection of a hexagonal prism similar to that in Fig. 7 (equations (1)) with the parallelopiped in Fig. 6 (equations (2)), and it is the solid remaining inside both of those solids. The stress solid is completely defined by the level curves shown, the numbers on which are the values of S_z/S. The level curves indicate the fields of the points (S_x, S_y)

FIG. 9.



for given values of S_z. The level curve $S_z = 0$ is the same as the diagram in Fig. 4. Poisson's ratio, K, was again assumed equal to 0.3. Fig. 9 shows a photograph of a model of this solid.

The equivalent simple tension (the "ideal" or "reduced" stress), corresponding to given values of S_x, S_y and S_z, is found as the highest value of S computed from the twelve expressions (1) and (2). Which one gives the highest value depends on the ratio (and signs) of the stresses. The stress solid can be used in answering this question. If the stress point (S_x, S_y, S_z) lies within a pyramid having its vertex at the origin and a certain one of the faces as its base, then the expression used as equation of that base gives the highest value of S. Thereby it is, for exam-

ple, possible to decide whether in a given case a shear failure or a strain failure would occur if the three stresses were increased in the same proportion.

After the above discussion had been written there appeared an article on the same subject by B. P. Haigh.[1] He proposes a new theory, namely, that the elastic limit is reached when the resilience or elastic energy per unit-volume has a certain definite value. He represents the laws following from this "*maximum resilience theory*" by the same graphical methods as those applied in the above discussion, and he finds thereby an ellipsoid instead of the stress solid in Figs. 8 and 9, and an ellipse instead of the diagram in Fig. 4. By comparing the proposed laws with results of previous tests (by Guest, Crawford, Batson, Mason, Turner, Sears, Scoble, and Cook and Robertson) he finds these results in better agreement with the maximum resilience theory than with either Guest's shear theory or St. Venant's strain theory. The agreement of the theory with the experimental results is least satisfactory in the case of equal biaxial tension, where the resilience theory, with Poisson's ratio $K = 0.3$, leads to the limiting stress $S_x = S_y = 0.845\,S$; that this value is too low is indicated both by the data quoted and, still more clearly, by Becker's results (to which no reference is made). With certain other combinations of stresses the agreement with the test data is very satisfactory, but in most of these cases the maximum shear and maximum strain theory gives very nearly the same results as the resilience theory. In fact, the diagram in Fig. 4 does not differ greatly from the ellipse, except at the two rectangular corners. Moreover, the limiting three-dimensional stresses found in the tests of thick cylinders by Cook and Robertson, and quoted by Haigh as supporting the resilience theory, agree very well with the maximum shear and maximum strain theory when the proposed shear limit $0.6S$ is used (instead of $0.5S$ with Guest's law). When all test data known at present are considered, then it seems that the experimental results support the maximum shear and maximum strain theory at least as well as or perhaps somewhat better than they do the maximum resilience theory. Further test data will be needed, however, before a final decision can be made.

[1] B. P. Haigh: The Strain-Energy Function and the Elastic Limit, *Engineering* (London), Jan. 30, 1920.

ELECTROLYTIC CONDUCTIVITY IN NON-AQUEOUS SOLUTIONS. IV. THE SOLVATION OF THE IONS OF TRIMETHYL-PARA-TOLYL-AMMONIUM IODIDE IN A NUMBER OF ORGANIC SOLVENTS.*

BY

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THE question of a union between the solute and the solvent has been the subject of very systematic and extensive investigations by the late H. C. Jones and his co-workers, since the beginning of the century. The results of these researches led to the formulation of the *Solvate Theory of Solution,* which has been very useful in explaining certain apparent exceptions to the electrolytic dissociation theory of Arrhenius, presented by concentrated solutions. According to this theory, the ions and some of the molecules of the solute have the power to combine with more or less of the solvent.[1]

In a recent paper on the influence of the molecular magnitude of the solute on the conductance of its ions, Walden [2] has shown that the degree of solvation of the ions of the solute, *i.e.*, the number of moles of solvent combined with the ions, may be calculated from a knowledge of the limiting value of the conductivity, Λ_∞, of the solute, its molecular weight, M, the viscosity of the solvent, η_∞, and the molecular weight, M_0, of the latter. In this paper he has shown that the value of the constant in the expression:

$$\Lambda_\infty \cdot \eta_\infty = \text{const.}, \quad \ldots \quad (1)$$

depends upon the molecular weight of the solute; and that for solutions of a number of solutes in various solvents the product of the limiting value of the conductivity, the viscosity of the solvent, and the square root of the molecular weight of the solute has the same value, *i.e.*, at 25°,

$$\Lambda_\infty \cdot \eta_\infty \cdot M^{1/2} = 11.15. \quad \ldots \quad (2)$$

* Communicated by Professor Creighton.

[1] A resumé of the evidence bearing on the solvate theory of solution, and a detailed discussion of the significance of the theory will be found in this JOURNAL, **176**, pp. 479–564 and pp. 677–710 (1913).

[2] Walden, P.: Z. Elektrochem., **26**, 65 (1920).

When the ions of the solute are solvated, the molecular weight of the solute will have a greater value than that calculated from its chemical formula. In such cases, when the solute is not polymerized, the value of the constant in equation (2) will have a value smaller than 11.15, and the weight, Δ, of solvent combined with the ions is given by the expression:

$$\Delta = \left(\frac{11.15}{\Lambda_\infty \cdot \eta_\infty}\right)^2 - M. \quad \ldots\ldots\ldots \quad (3)$$

From this it follows that the number of moles of solvent combined with the ions, or the degree of solvation, is $\frac{\Delta}{M_0}$.

Recently the writer studied [3] the electrolytic conductivity of trimethyl-para-tolyl-ammonium iodide — $C_7H_7N(CH_3)_3I$ — in several organic solvents at 25°. The data obtained in this investigation have been used to calculate the extent to which solvation of the ions of trimethyl-para-tolyl-ammonium iodide occurs in a number of the solvents. The results of these calculations are given in Table I.

TABLE I.

Solvent	η_∞^{25}	Λ_∞^{25}	$\Lambda_\infty^{25} \cdot \eta_\infty^{25}$	$\Lambda_\infty^{25} \cdot \eta_\infty^{25} M^{1/2}$	$\Delta = \left(\frac{11.15}{\Lambda_\infty^{25} \cdot \eta_\infty^{25}}\right)^2 - M$	$\frac{\Delta}{M_0}$
Propylaldehyde	0.00435	120	0.414	6.89	448	7.73
Epichlorhydrin	0.0103	44	0.453	7.54	328	3.44
Ethyl alcohol	0.0112	48	0.538	8.96	152	3.30
Methyl alcohol	0.00580	100	0.580	9.65	93	2.91
Benzaldehyde	0.0140	33	0.462	7.69	305	2.88
Anisaldehyde	0.0422	13	0.464	7.72	300	2.21
Propionitrile	0.00413	143	0.591	9.84	448	1.44
Acetone	0.00316	188	0.594	9.89	75	1.29
Nitromethane	0.00619	115	0.712	11.85	0	0
Nitrobenzene	0.0182	38	0.692	11.52	0	0
Benzonitrile	0.0125	54	0.675	11.22	0	0

Since it has been shown by Walden [4] that the iodine ion is not solvated in methyl alcohol, ethyl alcohol, acetone and nitrobenzene, it may be assumed that this ion has little or no tendency to combine with solvents. On this assumption, the degree of solvation of trimethyl-para-tolyl-ammonium iodide in the different solvents given in the last column of Table I probably represents the degree of solvation of the trimethyl-para-tolyl-ammonium

[3] Creighton, H. J. M., and Way, D. H.: This JOURNAL, **186**, 675 (1918).
[4] Walden, P., *loc. cit.*, p. 69.

ion $[C_7H_7N(CH_3)_3]^+$. The results given in the table show that this ion does not combine with the solvent in solutions of either nitro-compound, or in solutions of benzonitrile; and that its greatest tendency to solvate is exhibited in solutions of aldehydes, the degree of solvation decreasing as the molecular weight of the aldehyde increases:

Solvent	M_o	M_s	$\frac{\Delta}{M_o}$
Propylaldehyde, C_2H_5CHO	58		7.73
Benzaldehyde, C_6H_5CHO	106		2.88
Anisaldehyde, $CH_3OC_6H_4CHO$	136		2.21

DEPARTMENT OF CHEMISTRY,
SWARTHMORE COLLEGE,
April 9, 1920.

On the Excitation of the Spectra of Carbon, Titanium, and Vanadium by Thermelectronic Currents. A. G. HEMSALECH. (*Philosophical Magazine*, March, 1920.)—Flawless plates of Acheson graphite, 37 mm. long, 10 mm. wide, and .95 mm. thick, covered on the upper side with a layer of powdered carborundum one-eighth of an inch thick to reduce the heat loss, were heated in air to temperatures ranging from 1700° to 3300° C. by electric currents of from 125 to 260 amperes. The maximum life of the plates at the higher temperatures was not more than 10 seconds.

As the temperature rises after the current begins to flow, yellowish vapors begin to form along the lower surface and a stream of such vapor rises from above the plate. At about 2400° C. the lower vapor turns bluish gray and assumes a sharply defined form, bulging downward. There is also a red-color region chiefly above the plate. The various colors are due to light emitted by vapors driven out from the carbon and the carborundum. When the plate is heated to about 3000° C. just below the lower surface there appears a sharply bounded band of pinkish hue one or two mm. deep, the "red fringe." "To investigate its origin, the plate was put in a horizontal magnetic field, so that the current and lines of force were at right angles. At 2700° the red fringe is usually invisible. When the force exerted on the current by the field was downward at this temperature, the fringe came to view. On reversing the field it disappeared. At 3000° C., at which temperature the fringe is normally developed, the application of the field in one direction makes the fringe appear above the plate and causes it to disappear from below it. The removal of the field is followed by the disappearance of the fringe above and by its reappearance below." Part of the heating current had passed out of the graphite plate into the space below and its path was revealed by the formation of the red fringe. Hemsalech distinguishes this current which he designates "thermelectronic" from

the thermionic currents of Richardson, holding that the former are due to the displacement of lighter particles than are the latter.

"Spectroscopic examination has revealed the existence of two entirely different and distinct emissions by the luminous vapors in the neighborhood of the heated plate. One of these emissions is controlled by the plate temperature and is due to thermo-chemical excitation. The lines and bands which compose its spectrum are observed to die out only gradually on passing away from the plate. The second emission is confined to the immediate vicinity of the plate, and in extent it coincides with the red fringe. It is further shown that this emission is controlled by the thermelectronic current and is therefore due to thermo-electric excitation. The characteristic feature of its spectrum is that its lines and bands, unlike those of the first emission, stop quite abruptly at the lower edge of the red fringe."

The red-fringe spectrum is made up of carbon bands, lines of titanium and of vanadium and of a group of hazy red bands attributed to the oxide and carbide of calcium.

G. F. S.

An Attempt to Determine if Common Lead Could be Separated Into Isotopes by Centrifuging in the Liquid State. J. JOLY and J. H. J. POOLE. (*Philosophical Magazine*, March, 1920.)—Among the descendants of both the thorium and the uranium radioactive family is an element which is isotopic with ordinary lead but differing from it a little in atomic weight and in density. Ordinary lead seems to be a mixture of these two isotopes. An attempt was made to separate the two constituents in a centrifuge as milk and cream are separated. The lead was maintained liquid by an electric current. After the centrifuge had been run for an hour at 9000 r.p.m. the lead was removed in six portions and the density of the top and bottom lots was measured. No evidence at all for any separation effect was obtained. After the initiation of the experiments a discussion of the possibilities of the method employed made clear that with the peripheral velocities of the centrifuge no separation should be detected, as the errors of observation would mask any difference of density. The Irish investigators are, however, confident that with a centrifuge running with higher peripheral velocity definite results should manifest themselves.

In a second paper in the same issue of the *Philosophical Magazine* the same authors report that they failed to separate the silver from the lead in alloys of these two metals, thus failing to find a substitute for cupellation. In the case of Pb-Sn and Pb-Sn-Bi alloys there was found a distinct difference between the upper and lower lots, amounting in one case to 1.8 per cent. "It is of interest that a definite alloy like tin-lead alloy, which is of the composition PbSn, should be capable apparently of being separated by the action of the centrifuge."

G. F. S.

PHENOMENA OF DRYING WOOD.*

(Second Article.)

An Analogistic Explanation of "Casehardening" or the Relations of "Set" and Stresses that Occur in Drying Wood.

BY

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INTRODUCTION.

In a previous article (July, 1919, pages 27–50) an explanation was given of the peculiar conditions of shrinkage, internal stresses and "sets." These conditions occur when a green piece of wood dries, and they give rise to the phenomenon of "casehardening," as it is called for lack of a more definite term. An analysis was also given of the stresses that occur progressively from the surface to the interior of the block. It is because of these phenomena, and particularly because of the "setting" of the molecular structure as a result of the process of drying, that wood may be bent in various ways and will remain so without restraint after it is dry. If the piece of bent wood is steamed, however, or even thoroughly soaked, it will return nearly to its original shape, provided it has not been stressed beyond the rupture point in bending. Furthermore, these same phenomena are what cause all the troubles encountered in drying wood, such as surface checking, "honeycombing" or internal checking, and warping.

To the uninitiated, or the person who has not made a thorough study of the subject, the behavior of wood in drying is frequently mystifying, and erroneous ideas and conclusions have resulted. There are three *partially independent* variables and one *dependent* variable that enter into the consideration. These are, first, the normal shrinkage of the wood with the removal of the hygroscopic moisture; second, the "set" or fixation of the molecular structure with a decrease in moisture; and third, the increase

* Communicated by the Director of the Forest Products Laboratory, Madison, Wisconsin.

in strength and hardness of the wood substance, each of these three being directly dependent upon the moisture condition, which is the fourth variable. All of these factors influence the internal stresses and the resulting form or dimensions of the block. It should be further noted that the shrinkage is a complex variable dependent also upon the direction of the grain and the density of the block. In general, normal shrinkage is twice as much circumferentially of the log, and about one-fiftieth as much longitudinally, as it is radially.

There is a mechanical analogy to the inter-relation of shrinkage, "set," strength, and moisture in which there is so close a correspondence to the actual physical phenomena that it may be used not only to clarify the conception, but even to predict what will take place under a given set of new conditions. It is the purpose of this paper by means of this simple mechanical analogy to make these somewhat vague ideas more clear.

A CLARIFYING ANALOGY.

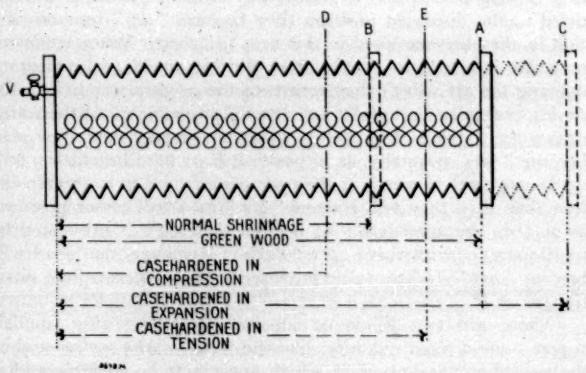
Imagine an "accordion-plaited" bellows (Fig. 1)[1] about a foot long and, say, three inches square, hermetically tight, but with a small air valve, *V*, in one end, which may be opened or closed to permit the outflow or inflow of air. Also imagine inside the bellows a coiled-wire spring of medium strength but sufficiently strong to hold the bellows open in a neutral position, so that, after being stretched or compressed, the accordion will return to this neutral position. This may be called position *A*.

Now, when the valve is open, we have very nicely represented a piece of green or steamed wood. The bellows may easily be stretched or compressed and will return to its initial position *A*, the spring alone offering resistance to deformation. Now draw a partial vacuum and close the valve; the neutral position becomes less than *A*, say *B*, and a piece of dry wood is represented. The apparatus may now be extended or compressed with much more difficulty, as not only the spring but the air also offers resistance to deformation; however, it will always return to the position *B*. This represents the increase of strength that occurs in dry as compared with green wood, as well as the "set" that takes place

[1] The illustration is presented with the caution that the air, spring, and other figures used are wholly analogical in significance, and that it is the relations and effects that are to be compared.

under normal shrinkage. On the other hand, suppose that through the open valve air is forced into the bellows, and the valve is then closed. The neutral position will now be greater than *A*, as *C*, representing a "set" in an expanded condition of the wood. Or, suppose that a greater vacuum than before is created within the bellows, so that the neutral position becomes less than *B*, say *D*, with the valve closed. This represents a "set" condition in which the wood is compressed beyond its normal shrinkage. Both *C* and *D* represent a "set" condition of the wood, which is the primary factor in causing casehardening and

FIG. 1



also in fixing the shape of bent wood as a result of the process of steaming, bending and subsequent drying in the bent condition.

This analogy is particularly illuminating, since it may be used to interpret and predict actual phenomena that take place in wood, although the causes are, of course, not identical in the two instances. The apparatus with the open valve represents green or steamed wood when it is in a plastic condition and may easily be stretched or compressed. Closing the valve is equivalent to "setting" the wood, and the matters of shrinkage or dimensions are dependent upon the air pressure in the bellows at the time the valve is closed. Shrinkage is represented by drawing a vacuum with the valve open, and the "setting" takes place at any

degree of vacuum or air pressure when the valve is closed. It will be seen that there is always a tendency for the wood to return to its initial green condition whenever it is soaked or steamed, just as the accordion will return to its position *A* as soon as the valve is opened. Shrinkage to *B* is "normal shrinkage," but to *D* it is "set," under compression stress, and to *E* or *C* under tensile stress.

It seems probable that there is a very similar occurrence with respect to the molecules of the wood itself. Although the molecules have a normal position relative to one another, to which they tend to return when they become wet after being stressed, they may be displaced from this position by means of force, and when dried in the displaced position they become "set" temporarily, that is, they become fixed in this new situation. When sufficient moisture is added to render them flexible again (equivalent to opening the air valve) they return to the original condition. In drying normally (not under any stress), the removal of the water draws the particles together to a certain degree, and they also become "set" normally, as in position *B* of the illustration; but, while wet (valve open), if they are compressed to a greater extent than this, they will become "set" in a still closer position, as at *D* in the accordion. If normal shrinkage is prevented by tensile stress (with valve open) during shrinkage, the wood will become "set" (when valve is closed) in an intermediate position, as at *E*.

There are two kinds of internal stress resisting applied forces—one a fixed quantity, like the force of the spring within the accordion; and another, which appears to be variable and is dependent upon the distortion of the wood during its process of drying from the green or wet condition. This second stress corresponds to that offered by the air pressure within the bellows when the air valve is closed, and is of a temporary nature.

THE SELECTION OF GLASS FOR THE MANUFACTURE OF AMPULS.*

BY

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THE selection of and requirements for glass bottles for storing the ordinary elixirs, fluidextracts, powders, tablets, etc., employed in pharmacy is a crude process, indeed, in comparison with the careful tests required for the selection of a proper glass for the manufacture of ampuls. This care is necessitated by reason of the fact that unselected glass may possess sufficient free alkali, or may be capable of yielding sufficient free alkali under the stress of the sterilization process which ampul solutions are required to undergo, or may yield sufficient alkali in the period during which they are necessarily kept in stock before being sold, to cause the precipitation of a portion of the alkaloidal base of a solution of alkaloidal salt when placed in the ampuls, and because unselected glass may throw off spicules or splinters of glass under the stress of the sterilization process or during storage. It is sufficient merely to point out, in order to show the unsuitability and even danger in the use of improperly selected glass, that precipitation of alkaloidal base will result in the lowering of the efficacy of an ampul solution upon which a physician may be relying in a serious case of illness and the production of spicules or splinters of glass in the ampul solution may result in discomfort, local irritation, or possibly more remote and more dangerous consequences. The use of a slight addition of acid to ampul solutions in an effort to correct for the alkalinity of unselected or improperly selected glass is contra-indicated in view of the fact that glass can be made or selected which requires no use of acid. The use of acid is also contra-indicated because acidity is usually productive of irritation at the site of injection.

In outlining tests for the selection of glass for the manufacture of ampuls the working of the glass under the flame must also be considered. In addition, other tests which may act as checks on the "alkalinity," "spicule" and "flame" tests are

* Communicated by the Author.

frequently resorted to. The series of tests mentioned below will, as a rule, be sufficient for proper selection of glass, if applied "secundum artæ." However, the "art," particularly the "flame" testing can be attained only by practical experience.

TESTS FOR THE SELECTION OF GLASS FOR THE MANUFACTURE OF AMPULS.

Size of tubing, thickness of wall, freedom from certain proscribed ingredients, color: in accordance with specifications.

"Working under the flame": can be judged only by practical experience obtained by comparison of many varieties of glass.

Standard: greatest ease in working consistent with the other requirements.

"Alkaloidal Alkalinity Test"—"General."—A 1 per cent. solution of U. S. P. morphine sulphate or a 0.2 per cent. solution of U. S. P. strychnine sulphate in normal saline solution must not develop crystals or become turbid or opalescent when sterilized under practical conditions in ampuls made from the glass undergoing test; the ampuls having been treated with dilute hydrochloric acid and finally thoroughly washed free from acid and dried before the alkaloidal solution is placed in them. The preferred test is the "particular" one which is in all respects similar to the "general" test except that the particular solution which is intended to be marketed in the ampuls is used in place of the morphine sulphate or strychnine sulphate solutions.

"Spicule Test."—Work the glass into ampuls. Place a 0.6 per cent. NaCl solution (or any particular solution) in the ampuls; seal and sterilize under practical conditions. The solution is then carefully examined under a magnifying glass for spicules or splinters of glass.

Exact conformity with the above tests is absolutely necessary in order to permit the use of any particular glass for the manufacture of ampuls.

The following tests are applicable for comparative purposes only, and are occasionally employed as confirmatory checks:

"Phenolphthalein Alkalinity Test."—Treat the glass with dilute HCl followed by very thorough washing. Boil a sample corresponding to 500 sq. centimetres of surface for 16 hours with distilled water, keeping the sample covered with fresh additions of water as required. Remove the glass, add 1 c.c. phenolphthalein test solution to the water in which the glass was boiled

and titrate to neutrality. Make a correction on the water, vessel in which the boiling was conducted, locality in which the test was carried out, etc., by running a blank under precisely the same conditions employed in making the test, and at the same time. Report alkalinity as milligrams of NaOH per 100 sq. cm.

"Loss to Water Test."—The sample used in the "phenolphthalein alkalinity test" is weighed before and after boiling. Report loss as milligrams per 100 sq. cm.

"Vulnerability to Alkaline Fluids Test."—Repeat the "loss to water test," using a new sample and using 2 per cent. sodium carbonate solution in place of water, keeping up the volume by fresh additions of water only. Report loss as milligrams per 100 sq. cm.

"Phenolphthalein Alkalinity Autoclave Test."—Water containing a few drops of phenolphthalein test solution is placed in the ampul (which has previously been acid-washed and thoroughly rinsed with distilled water); the ampul is sealed and autoclaved at 12 lbs. steam pressure for 45 minutes. At the end of this time the tube is carefully examined for color and spicules. A pink color indicates alkalinity.

"Phenolsulphonephthalein Alkalinity Autoclave Test."—In all respects this is similar to the preceding test with the exception that a yellowish solution of phenolsulphonephthalein is used instead of phenolphthalein and the autoclaved liquid is examined for any reddish tint which may develop.

The following table shows some typical results obtained by the use of the several tests mentioned above in glass tubing offered for the manufacture of ampuls:

Sample No.	Color.	"Flame" test.	"Spicule" test.	"Phenolphthalein Alkalinity" test.	"Loss to Water" test.	Suitability.
1	Flint	O. K.	None	0.098 mgm.	0.7 mgm.	O. K.
2	Flint	Works hard	Spicules	.....	4.2 mgm.	Not O. K.
3	Flint	Works easily	Spicules	.....	1.9 mgm.	Not O. K.
4	Flint	Works easily	None	Undeter. trace	0.61 mgm.	O. K.
5	Flint	Works easily	None	0.102 mgm.	1.1 mgm.	O. K.
6	Flint	Works hard	Spicules	.....	Unweighable	Not O. K.
7	Flint	Works easily	None	.....	0.62 mgm.	O. K.
8	Flint	Works easily	None	.....	0.49 mgm.	O. K.
9	Flint	Works easily	None	.....	3.2 mgm.	O. K.
10	Flint	Works easily	A few spicules	.....	4.4 mgm.	Not O. K.

All of these samples yielded perfect results in the "alkaloidal alkalinity" test. As a matter of fact, after a satisfactory source has been established, it is only occasionally that a sample fails to answer this requirement, but this occasional exception illustrates the necessity for the application of this test.

The relation between the alkalinity yielded in the "phenolphthalein alkalinity" test and the result of the "alkaloidal alkalinity" test was not determined, the "phenolphthalein alkalinity" test being rejected in favor of the shorter and more practical "alkaloidal alkalinity" test.

The phenolphthalein and phenolsulphonephthalein alkalinity autoclave tests are used by some workers, but they are open to the criticism that they bear no practical direct relation to the possible use of the glass for ampul purposes, whereas in the same time and with no more labor a direct result can be obtained by the use of the "alkaloidal alkalinity test."

No definite information can be obtained regarding the possible formation of spicules by a glass, from its working qualities under the flame. In the experience of some workers, the hard glasses appear to suffer surface scaling under the influence of the moisture and heat used in autoclaving, whereas in the experience of others, the more easily worked and more soluble glasses yield spicules by surface erosion due to solution of the alkaline radicle of the glass.

The results yielded by the application of the "phenolphthalein alkalinity," "loss to water" and "vulnerability to alkaline fluids" tests to some samples of glass tubing, bottles, Erlenmayer flasks, test tubes and beakers are herewith appended as a matter of comparison and of interest:

Sample.	Color.	"Phenolphthalein Alkalinity" test.	"Loss to Water" test.	"Vulnerability to Alkaline Fluids" test.
Tubing	Flint	Undeterminable trace	Unweighable	21.0 mgm.
Tubing	Flint	.....	1.5 mgm.	.....
Tubing	Flint	Undeterminable trace	Unweighable	30.0 mgm.
Tubing	Flint	.....	1.17 mgm.	.....
Tubing	Flint	Undeterminable trace	Unweighable	24 mgm.
Tubing	Flint	Undeterminable trace	Unweighable	8.25 mgm.
Tubing	Flint	.....	1.2 mgm.	.....
Tubing	Flint	.....	4.0 mgm.	22.5 mgm.
Tubing	Flint	.....	2.5 mgm.	43.5 mgm.
Tubing	Flint	.....	0.62 mgm.	.....
Tubing	Flint	.....	2.5 mgm.	31.5 mgm.
Tubing	Flint	.....	3.0 mgm.	27.5 mgm.
Tubing	Flint	.....	3.1 mgm.	.....
Tubing	Flint	.....	3.5 mgm.	24.0 mgm.
Tubing	Flint	.....	Unweighable	9.25 mgm.
Tubing	Flint	Undeterminable trace	Unweighable	6.5 mgm.
Tubing	Flint	.....	Unweighable	20.0 mgm.
Tubing	Flint	.....	Unweighable	17.5 mgm.
Tubing	Amber	.....	Unweighable	2.65 mgm.
Tubing	Amber	.....	Unweighable	2.0 mgm.
Tubing	Amber	.....	8.0 mgm.	56.5 mgm.
Tubing	Amber	.....	1.5 mgm.	22.5 mgm.
Tubing	Amber	.....	3.0 mgm.	27.5 mgm.
Tubing	Amber	.....	4.0 mgm.	19.0 mgm.
Tubing	Amber	.....	5.0 mgm.	12.5 mgm.
Tubing	Amber	.....	8.0 mgm.	25.0 mgm.
Tubing	Amber	.....	10.0 mgm.	57.5 mgm.
Tubing	Amber	.....	Unweighable	7.5 mgm.
Tubing	Amber	.....	Unweighable	7.8 mgm.
Tubing	Blue	.....	0.15 mgm.	1.8 mgm.
Bottle	Flint	.....	0.45 mgm.	.....
Bottle	Flint	.....	0.59 mgm.	.....
Bottle	Flint	.....	0.39 mgm.	.....
Erlenmayer flask	Flint	.....	0.0107 mgm.	.....
Test tubes	Flint	Undeterminable trace	0.28 mgm.	.....
Beaker	Flint	Undeterminable trace	3.0 mgm.	.....
Beaker	Flint	.....	Unweighable	3.3 mgm.
Beaker	Flint	Undeterminable trace	Unweighable	18.5 mgm.
Beaker	Flint	Undeterminable trace	Unweighable	13.0 mgm

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The Measurement of Projectile Velocities. PAUL E. KLOPSTEG and MAJOR A. L. LOOMIS. (*Jour. Am. Inst. Elec. Eng.*, Feb., 1920.)—During the war the Aberdeen Chronograph was developed. By reason of the use of standard parts one complete instrument could be delivered in one working day. Under actual working conditions one round could be fired and all the readings taken in forty-five seconds.

Instead of breaking electrical circuit by rupturing a wire, as was done in the Boulengé chronograph, the projectile closed the circuit by making contact between two pieces of lead foil. When contact is thus established, current flows through the primary of a transformer. The current developed in the secondary flows through the registering device. A constant speed motor carries on its vertical shaft an aluminium drum within which fits a strip of specially prepared paper. The current from the secondary passes as a spark from a point to the metal of the drum, making a mark on the paper. After the projectile has travelled 50 feet further, it closes a second circuit and a second mark is registered on the paper. With a fixed distance between targets and with constant speed of rotation of the drum the velocity sought was proportional to the distance between the two marks on the strip of paper. A scale was accordingly made on which the velocity was read off directly merely by applying the paper to it.

G. F. S.

Caramel.—G. P. PLAISANCE and HELEN MONSCH, of the Iowa State College and Agricultural Experiment Station, have studied the occurrence of furfural in caramel (*Journal of Home Economics*, 1917, ix, 167–171). Caramel is used as a coloring, *e.g.*, in artificial vanilla extract, and is formed from sugar in cooking. Furfural, furfurole, or furfuraldehyde is an heterocyclic aldehyde which is volatile in steam. It is somewhat toxic, thus 0.1 gram causes headache in man and 0.5 gram kills a cat or a rabbit. Some furfural is formed when sugars, especially cane sugar, are caramelized at a temperature ranging from 180° to 200° C.; the greatest production of furfural noted was 0.944 gram from 1 kilogram of cane sugar on caramelization for four minutes at 200° C. However, the furfural is completely expelled if the caramel be boiled with an equal amount of water for ten minutes in an open pan. No precautions to prevent the injurious action of furfural are necessary when the food is cooked in the presence of water after caramelization, as in the preparation of cakes, frostings, and rice pudding. In candy-making the cooking should be conducted at as low a temperature as possible, since the yield of furfural increases with the temperature. Care should be taken to prevent caramelization in the baking of fruits; it is desirable to boil caramelized fruit syrups with an equal volume of water for ten or fifteen minutes before serving them.

J. S. H.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

AN INTEGRATION METHOD OF DERIVING THE ALTERNATING CURRENT RESISTANCE AND INDUCTANCE OF CONDUCTORS.[1]

By Harvey L. Curtis.

[ABSTRACT.]

IN connection with some work on alternating current resistance and inductance, the Bureau of Standards recognized the need of formulas taking into consideration the so-called "Skin Effect" due to the proximity of the conductors.

The solution of the problem was met by a process of integration. The conductor is divided into infinitesimal filaments by surfaces which coincide with the lines of flow. The magnetic field at any point is the sum of the magnetic fields of all these filaments. The counter-electromotive force in a filament is determined by the rate at which the magnetic fields of all the others cut this filament.

Formulas for the alternating current resistance and inductance of a straight cylindrical conductor were derived by both the use of real and imaginary power series. These formulas correspond exactly with the asympotic formulas of Russell (*Phil. Mag.*, 17 p. 524, 1909).

The same method is applied to a return circuit making use of imaginary series, and formulas for the alternating current resistance and inductance are derived. Values computed by these formulas are compared with experimental results.

THE CHARACTERISTICS OF STRIÆ IN OPTICAL GLASS.[2]

By T. T. Smith, G. E. Merritt, and A. H. Bennett.

[ABSTRACT.]

STRIÆ are imperfections in optical glass which are revealed by, and cause consequent damage because of, their refractive index being slightly different from the surrounding glass. Various methods for detecting their presence are described and photographic illustrations by a highly sensitive method given.

* Communicated by the Director.

[1] Scientific Paper No. 374.

[2] Scientific Paper No. 373.

The comparative effects of striæ on the definition given by binocular prisms, in which striæ are present in different degrees, are exhibited by photographs of an artificial star taken through these prisms. Prisms which had been discarded because of the presence of striæ in them, except where these show up in dense nests, were found to give as good definition as those having no appreciable striæ.

The refractive indices of the striæ were measured for a number of samples by a total reflection refractometer and found to be above or below that of the surrounding glass by about 2 in the fourth decimal place.

From the investigation, it is concluded that in most visual work a few striæ do real damage only when in focus or nearly in focus in the field of view. The scattering effect of a few striæ is probably detrimental only in astronomical and certain kinds of microscopic work.

A NEW CADMIUM VAPOR ARC LAMP.[3]

By Frederick Bates.

[ABSTRACT.]

FOR some years numerous experiments have been carried out by a number of investigators with the object of obtaining a cadmium vapor lamp similar to the mercury vapor lamp. This has been done owing to the necessity for securing a stable monochromatic red-light source of high intensity. When pure cadmium is distilled into the quartz lamp and freezes, the metal adheres to the silica with such tenacity as to either crack the lamp or peel strips of the silica from the walls. If such a lamp be filled with a cadmium-mercury alloy, the cadmium spectrum appears but faintly, and the position of its principal lines in the spectrum with respect to the mercury lines is such that spectrum filtration with a wide slit is impracticable. The lack of intensity in the cadmium is due to the fact that its vapor pressure is relatively low compared with that of mercury.

In the present investigation it was discovered that the metal gallium would readily alloy with cadmium, and that a very small quantity, less than one per cent., was sufficient to radically change the character of the cadmium and greatly reduce its tensile

[3] Scientific Paper No. 371.

strength. All breakage of the lamp was eliminated. In using this alloy in a quartz vapor lamp, the cadmium spectrum is obtained with great brilliancy and purity. Although gallium melts at approximately 30° C., its boiling point is above 1600° C., and its vapor pressure is so low that the spectrum of gallium is practically absent, the cadmium vapor acting as the carrier of the electric energy. The utilization of the cadmium spectrum is greatly facilitated by the fact that the gallium lines appear but faintly and that the spectrum of gallium has no lines between 4200A and 6400A. A lamp of this type, using lead seals to render the electrodes proof against leakage can be operated continuously with no variation in the high intensity of the cadmium lines and appears to have an indefinite life.

WAVE LENGTHS LONGER THAN 5500Å IN THE ARC SPECTRA OF SEVEN ELEMENTS.[1]

By C. C. Kiess and W. F. Meggers.

[ABSTRACT.]

THE concave grating spectograph of the Bureau of Standards was used to photograph the yellow, red and infra-red arc spectra of titanium, chromium, manganese, molybdenum, tungsten and uranium. This work is a continuation of a program of standard wave-length determination and spectroscopic analysis which has as one of its objects the mapping of the spectra of chemical elements as far out into the region of long wave lengths as modern photographic methods will permit.

The spectrograms were made on photographic plates sensitized to the long waves by bathing in solutions of dyes. Recently "made-in-America" dyes were used for many of the plates and were as effective in their photosensitizing action as the imported ones.

The wave lengths of more than 2500 spectral lines were derived from the measurement of the plates. These wave lengths extend from the green at 5500 Å into the infra-red beyond 9700 Å. So far as known, impurity lines and spurious lines have been eliminated from the wave-length tables. Frequency differences which are suspected of being constant have been found in each of the spectra here presented.

[1] Scientific Paper No. 372.

RECOMMENDED SPECIFICATIONS FOR WHITE PAINT AND TINTED PAINTS MADE ON A WHITE BASIS, SEMI-PASTE AND READY MIXED.[4]

[ABSTRACT.]

PREPARED and recommended by the U. S. Interdepartmental Committee on Paint Specification Standardization January 26, 1920. This committee was appointed at the suggestion of the Secretary of Commerce, and consisted of representatives of the War, Navy, Agriculture, Interior, Post Office, Treasury, and Commerce Departments, the Railroad Administration, the Panama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The committee submitted a preliminary draft of the specifications to a large number of representatives of the paint and varnish manufacturers, and gave careful consideration to the replies received.

RECOMMENDED SPECIFICATIONS FOR RED LEAD, DRY AND PASTE.[5]

[ABSTRACT.]

PREPARED and recommended by the U. S. Interdepartmental Committee on Paint Specification Standardization January 26, 1920. This committee was appointed at the suggestion of the Secretary of Commerce, and consisted of representatives of the War, Navy, Agriculture, Interior, Post Office, Treasury, and Commerce Departments, the Railroad Administration, the Panama Canal, and the Educational Bureau of the Paint Manufacturers' Association of the United States. The committee submitted a preliminary draft of the specification to a large number of representatives of the paint manufacturers, including the manufacturers of red lead, and gave careful consideration to the replies received.

AN INVESTIGATION OF THE PHYSICAL PROPERTIES OF DENTAL MATERIALS.[7]

By Wilmer H. Souder and Chauncey G. Peters.

[ABSTRACT.]

PROPERTIES, such as crushing strength, flow, thermal and chemical expansion, chemical composition, electrode-potentials

[4] Circular No. 89.
[5] Circular No. 90.
[7] Technologic Paper No. 157.

and thermal reactions have been investigated. Additional phases, such as method of manipulation, time, temperature, etc., were found to exert definite influences upon the materials.

A number of commercial alloys, together with some special alloys, were tested. The thermal expansion of amalgams was found to be considerably greater than the expansions of normal teeth.

The apparatus generally used in testing these materials was found to be unsuited for accurate observations. More suitable instruments were selected and it is thought that the data supplied in this paper are of the highest accuracy and may be safely used as the basis for clinical interpretations.

The paper includes 25 photographs or drawings and three tables setting forth details of the investigation.

TWELFTH ANNUAL CONFERENCE ON WEIGHTS AND MEASURES, 1919.[1]

[ABSTRACT.]

THE Annual Conference on Weights and Measures is a national organization composed of State and local weights and measures officials throughout the United States. This body meets annually at the Bureau of Standards, Washington, D. C., for the purpose of discussing and solving problems relating to weights and measures, such as uniform legislation, rules and regulations and methods of enforcement of weights and measures laws, specifications and tolerances for all commercial apparatus, and the proper inspection and test of apparatus, etc. The present meeting was the twelfth one held, and the first since 1916, the sessions having been discontinued during the war. This report, which is a stenographic record of the proceedings, includes all papers read and resolutions adopted. Perhaps the most important single accomplishment of this Conference was the discussion upon and the tentative adoption of a set of specifications and tolerances for liquid-measuring pumps, especially those used in the sale of gasoline, kerosene, etc. It was agreed by the members that these should be thoroughly studied and tried out in the field and that final action upon them should be taken at the next meeting. The unsatisfactory condition of liquid-measuring pumps in all

[1] Miscellaneous Publication No. 41.

parts of the country rendered action on this important subject imperative if the purchaser was to receive the correct amounts.

Consideration was also given to a number of other subjects of importance, including the progress made in the various States and cities; the necessity of the Federal regulation of type of apparatus; the proper method of sale of ice and wood; the testing of railroad track and mine scales; the marking of wrapped hams and bacon with the net weight; the standardization of shipping containers; and the adoption of the metric system of weights and measures.

THE EXTRACTION OF RUBBER GOODS.[9]

By S. W. Epstein and B. L. Gonyo.

[ABSTRACT.]

THIS paper makes a complete study of the various extracts as determined in the analysis of rubber goods. The advantage of the use of mixed solvents, namely acetone-carbon bisulphide and acetone-chloroform, over the methods previously employed is described with considerable detail.

A mixture of 55 per cent. carbon bisulphide and 45 per cent. acetone by volume, boiling constantly at 34.25° C., is adopted rather than the acetone-chloroform mixture because of the less solvent effect of the acetone-carbon bisulphide mixture on the rubber. This makes it possible to eliminate the extraction with chloroform and to determine free sulphur directly in the extract, provided the bisulphide is properly purified before use.

A large number of figures are presented to show the distinct advantage of the use of a mixed solvent over the separate extractions with acetone and chloroform, particularly in cheap compounds when the material is not all removed by the separate extractions.

THE DOUBLE POLARIZATION METHOD FOR THE ESTIMATION OF SUCROSE AND THE EVALUATION OF THE CLERGET DIVISOR.[10]

By Richard F. Jackson and Clara L. Gillis.

[ABSTRACT.]

A SINGLE polarization of a sugar mixture fails to give an exact indication of the quantity of sucrose since the observed

[9] Technologic Paper No. 162.

[10] Scientific Paper No. 375.

rotation is but the resultant of the rotations caused by the individual constituents. Hence since we are concerned with two unknown quantities, namely the rotation of sucrose and the rotations of all other substances collectively, it is necessary to construct two equations. In the Clerget method one equation states that the direct polarization is the sum of the rotations of sucrose and the impurities; the other states that the invert polarization is the sum of the rotations of inverted sucrose and the impurities. It is therefore essential to know the change of rotation of sucrose before and after inversion and to be sure that the rotations of the impurities remain unchanged in the two polarizations. The value of the change of rotation of sucrose before and after inversion, which is known as the Clerget Constant, was found by Herzfeld [11] to be 132.°66 S if all readings are taken at 20° C.

In the present investigation the velocity of inversion of sugar and its dependence upon temperature and concentration of hydrochloric acid was measured by starting the reaction quickly and arresting it abruptly by neutralizing the acid. By use of special apparatus to accomplish rapid mixing of the reagents, it was possible to measure velocity to an extreme temperature of 90° C. and for time intervals as low as thirty seconds. The knowledge obtained in these experiments enabled us to determine the length of time necessary at each temperature to produce 99.99 per cent. inversion of sucrose. In an analytical process it is not feasible to carry out the inversion at a constant temperature, consequently the above described method was used to determine the progress of the inversion under the prevailing conditions of analysis. In Herzfeld's method the sugar solution is acidified at room temperature and is heated rapidly to about 69° C. for a total time of seven and one-half to ten minutes. We have found that four and one-half to five minutes is sufficient. There is thus a period of about five minutes in which the acid may act on the products of inversion and may cause a diminution of negative rotation. We have measured the rate of decomposition at various temperatures and found it large enough to be the cause of considerable error in analysis. A temperature of 60° C. in the presence of 5 ml concentrated HCl for a total heating period of nine minutes is much more suitable.

Applying the conditions most suitable for obtaining com-

[11] *Zeit. Ver. Zuckerind.* 38, p. 699, 1888.

plete inversion and for avoiding decomposition of invert sugar, we have found by a series of eight concordant experiments that the Clerget Constant should be 133.25 at 20° C. instead of 132.66 as found by Herzfeld. This value is the algebraic difference of two quantities, +100°, the rotation of 26 g of pure sucrose, and −33.25, twice the rotation of 13 g of sucrose inverted by 5 ml of concentrated HCl, both solutions being made up to 100 ml and observed at 20° C.

The next question concerns the constancy of rotation of impurities in the two polarizations. If invert sugar is present in the original material, its rotation is observed in neutral solution for the direct polarization and in acid solution for the invert polarization. The effect of acid on the rotation of invert sugar was measured and found to be expressed by the formula:

$$R = -32.00 - 0.125\,C$$

in which C represents the number of ml of 1 : 1 HCl contained in 100 ml of solution. There is thus a change of rotation upon acidification which in analysis is reported as sucrose. A study of the effect of other reagents showed that an equal weight of salt produced the same effect. The error is thus corrected by the addition of salt to the solution for direct polarization.

The above formula gives for the rotation of invert sugar in aqueous solution −32.00 which is exactly the value obtained by Browne [12] by inverting sucrose with invertase. The same formula gives for the rotation of invert sugar in the presence of 18.18 ml of 1 : 1 HCl the value −34.27. Browne [13] reports −34.22. Our formula gives for 28.59 ml of 1 : 1 HCl the value −35.57. Steuerwald [14] reports −35.58. Thus our formula correlates satisfactorily four widely separated points on a curve. Herzfeld's value −32.°66 lies 0.°6 away from this curve.

We have moreover determined the rotation of invert sugar in the presence of 10 ml 1 : 1 hydrochloric acid neutralized by ammonia (−33.91) and by sodium hydroxide (−34.02).

Four modifications of the Clerget Method have been proposed which are adaptable to the various types of sugar products. These methods and comprehensive tables are given in full in the extended article.

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[12] *J. Assoc. Off. Agr. Chem.* 11, p. 140, 1916.

[13] *Ibid.*, p. 136. Browne reports —34.9 for 23.64 g of sucrose. This becomes —34.22 for 13 g multiplied by 2.

[14] *Archief.* 21, p. 831, 1913. *Int. Sug. J.* 15, p. 489, 1913.

NOTES FROM NELA RESEARCH LABORATORY.*

COLOR MATCH AND SPECTRAL DISTRIBUTION.

By Edward P. Hyde and W. E. Forsythe.

WHEN two different radiators such as a tungsten and a carbon lamp are color-matched, *i.e.*, adjusted so that the integral color is the same, there has been some question as to the extent to which they have the same distribution of energy in the visible spectrum. This was tested out by one of the writers some years ago for carbon, tungsten and tantalum for a single temperature in the neighborhood of about 2160° K., and evidence was found that when the radiation intensities were set relatively equal at the two ends of the visible spectrum there was a difference at the centre of the spectrum of about one-half per cent. between a tungsten and carbon, and about twice this difference between carbon and tantalum. If two radiators have the same spectral distribution when they are color-matched, they can be brought to the condition for color-matching by measurements on the relative intensities of two spectral regions in different parts of the spectrum. Using an optical pyrometer first with a red, then with a blue glass screen before the eyepiece, four different radiators—a black-body, tungsten, tantalum, and untreated carbon—were set at the same relative intensity in the red and blue parts of the spectrum for several different temperatures. Measurements were then made with the pyrometer, using a green glass screen to see if the four radiators when thus matched in the red and blue were also matched in the green. It was found that if these four radiators were color-matched by determining the temperature for which the ratio of the red intensity to the blue intensity was the same, then the ratio of the red to the green was not what it should be if they had the same spectral distribution when they were thus color-matched. Taking the black body as the standard, the untreated carbon was found to be the same within experimental errors. The ratio of red to green for tungsten differed from that of a black body by about one-half per cent. for a temperature of about 1500° K. to about eight per cent. for a

* Communicated by the Director.

temperature of about 2900° K. For tantalum this difference was very nearly constant for a range in temperature from 1500° K. to 2700° K. and was equal to about 6 per cent.

THE GOLD-POINT PALLADIUM-POINT BRIGHTNESS RATIO.

By Edward P. Hyde and W. E. Forsythe.

IN a paper on "The Effective Wave-Length of Red Glasses," published in the *Astrophysical Journal* in November, 1915, appeared a note on some results on the gold-point palladium-point brightness ratio. This data was obtained by measurements with an ordinary disappearing-filament optical pyrometer with a red glass in the eyepiece.

Since that time additional data have been obtained by the same method. In addition some data have been taken on this ratio by means of a spectral pyrometer. In the work on this ratio several different black-body furnaces have been used. The sample of gold or palladium that was melted inside the black-body furnace was mounted between platinum wires supported by two porcelain tubes in such a manner that the central part of the sample could not touch either of these two tubes. This mounting was necessary as it has been found that if a single tube is used, sometimes the metal will touch and cling to the end of the tube so that the electric current through the two platinum wires and the sample used to give a signal when the sample melted would not be broken at the instant of melting and thus a high value would be obtained. In the table are given the results of measurements on the ratio.

SUMMARY OF RESULTS OF MEASUREMENTS OF THE GOLD-POINT PALLADIUM-POINT BRIGHTNESS RATIO.

Method	Number of Separate Determinations	Number of Melts Pd.	Au.	λ	Average of Ratio Found	Result for the Palladium Point
Ordinary pyrometer	10	45	45	0.6663	76.9	1828.6°K
Spectral pyrometer	3	13	12	0.6018	122.2	1828.3°K

The values for the palladium point were calculated from the ratios found, from the value of 1336° K. for the gold point and from $c_2 = 14350\mu$ deg. The range of values for the ratio found by means of the ordinary optical pyrometer is from one per cent. above to the same amount below the mean value given in the above

table. This range in the ratio corresponds to about one-twelfth of one per cent. in the value for the melting point of palladium. Thus the range due to this error is about ± 1.5° K. The range for the values using the spectral pyrometer was about the same, being in this case, somewhat less than one per cent. As a result of this work the Laboratories of the General Electric Company have decided, for the time being, to accept 1828° K. as the palladium point.

Alcoholic Fermentation in the Presence of Calcium Carbonate.—JOHANNES KERB (*Berichte der deutschen chemischen Gesellschaft*, 1919, lii, 1795–1800) has permitted both top yeast and bottom yeast to act on an aqueous solution of sucrose (cane sugar) and inorganic nutrient salts, to which calcium carbonate had been added. Both varieties of yeast produced a normal yield of alcohol. An insignificant increase occurred in the amount of acetaldehyde and of volatile acids, chiefly acetic acid. Not even traces of pyroracemic acid could be found. Alcoholic fermentation of sugars like glucose $C_6H_{12}O_6$ may be explained by formation of pyroracemic acid $CH_3COCOOH$, conversion of the latter into acetaldehyde CH_3CHO by loss of carbon dioxide CO_2, and reduction of the aldehyde to ethyl alcohol CH_3CH_2OH. However, calcium pyroracemate, like the free acid, is fermentable; this probably accounts for its failure to accumulate even though calcium carbonate was present to neutralize the pyroracemic acid as soon as formed.

J. S. H.

Action of Certain Organic Accelerators in the Vulcanization of Rubber.—G. D. KRATZ, A. H. FLOWER, and COLE COOLIDGE (*Journal of Industrial and Engineering Chemistry*, 1920, xii, 317–324) have reached the following conclusions in a research on this subject. The action of certain compounds, such as diphenythiourea, as accelerators is due to their tendency to decompose at the temperature and under the conditions of vulcanizing into simpler compounds which contain an active nitrogen group; the latter is responsible for the acceleration. The same accelerating action is exerted by equimolecular quantities of compounds which contain the same active nitrogen group in their primary nucleus. The accelerating action of the parent compound is decreased when hydrogen in the active nitrogen group is replaced by other and larger groups or radicals. The activity of the nitrogen is ascribed to a change in its valence from three to five with the temporary addition of sulphur; the active nitrogen group, therefore, functions as a sulphur-carrier.

J. S. H.

Forest Products Laboratory Decennial Celebration.—Preliminary arrangements are well under way for the observance at Madison, Wisconsin, during the latter part of June of the tenth anniversary of the opening of the Forest Products Laboratory. A large gathering of representatives from the various industries interested in the laboratory's work will be present and opportunity will be afforded for becoming more familiar with the extent and significance of its activities. Present plans call for a two-day meeting, with addresses by men of national reputation in science and industry, tours of inspection through the laboratory, informal discussions, and various forms of entertainment.

The Forest Products Laboratory is a branch of the United States Forest Service, established in 1910 in coöperation with the University of Wisconsin, and is a consolidation of a number of testing laboratories and other units of the Forest Service which had been located at various points throughout the United States. It is engaged principally in industrial research on problems connected with the manufacture and use of forest products, including besides lumber, posts, poles, ties, and similar products, pulp and paper, naval stores, hardwood and softwood distillation products, and other chemicals and pharmaceuticals. At the present time the laboratory employs about 200 people and occupies five buildings in whole or in part.

R.

Aniline Poisoning.—MAX NASSAUER (*Zeitschrift für angewandte Chemie*, 1919, xxxii (I), 333–335) states that a malignant tumor or cancer of the bladder occurs as an occupational disease among workmen who are exposed to the vapors of aniline. During a period of twenty-three years, from 25 to 30 per cent. of the tumors of the bladder, which came to operation at the surgical clinic of the University at Frankfurt am Main, were caused by aniline. The vapors of aniline are inhaled highly diluted with air; their effect on the bladder is slowly cumulative; the first symptoms of the cancer appear, on the average, when the workman has been employed in the factory for sixteen years. In order to reduce the danger to a minimum, the plant must be constructed of impervious materials and be amply ventilated; the evolved gases must be purified before their escape into the atmosphere; closed apparatus must be used; liquid raw materials and products must be handled with compressed air, solids by mechanical devices. Ample bathing facilities must be provided and used at the end of each day's work. Clean work clothes and wooden shoes must be worn daily, and gas-masks and rubber gloves must be used when necessary. The urine of the workmen should be examined at frequent intervals.

J. S. H.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE CONSTITUTION OF CAPSAICIN, THE PUNGENT PRINCIPLE OF CAPSICUM, II.[1]

By E. K. Nelson.

[ABSTRACT.]

SINCE the appearance of the author's first communication on this subject,[2] Lapworth and Royle[3] have published the results of their work on capsaicin.

As Lapworth and Royle are not fully disposed to accept the constitution of capsaicin as stated, further confirmation of its structure was sought in the regeneration of capsaicin. This synthesis was successfully accomplished, and the capsaicin formed found to be in all respects identical with the natural substance.

Synthetic vanillyl octoyl amide was found to resemble capsaicin closely in its stability toward boiling concentrated sodium hydroxide solution, and in its solubility in concentrated hydrochloric acid.

The decenoic acid isolated from capsaicin was found to yield, when fused with potassium hydroxide, acetic acid and octoic acid with a branched chain.

A PINK YEAST CAUSING SPOILAGE IN OYSTERS.[4]

By Albert C. Hunter.

[ABSTRACT.]

AN investigation of the cause of the pink color which develops in oysters during shipment was conducted on Narragansett Bay and in the oyster houses of Rhode Island. The organism responsible for the pink color was studied in detail, with the object of preventing its introduction into shipments of oysters. The results of this investigation are, in part, as follows:

* Communicated by the Director.

[1] Published in *J. Am. Chem. Soc.*, **42**, 597–9 (1920).

[2] *J. Am. Chem. Soc.*, **41**, 1115 (1919).

[3] *J. Chem. Soc.*, Trans., **115**, 1109 (1919).

[4] *U. S. Dept. Agr. Bull.* 819, issued March 10, 1920.

The organism causing a pink color in oysters is a yeast-like fungus found in large numbers in and about the oyster house, and occasionally present in oysters before being brought to the oyster house. About 3 per cent. of the samples of water from the oyster beds showed the presence of the pink yeast which, however, was never recovered from mud samples from the bottom of the bay.

Tests for acid, gas, alcohol, indole and phenol were negative. The yeast inverts saccharose and reduces nitrates to nitrites and ammonia. It produces a pink pigment which is insoluble in water, slightly soluble in alcohol and carbon disulphide, somewhat more soluble in chloroform, and very soluble in ether. Formaldehyde gas, 1 part to 2500 parts of water, kills the yeast.

The greater part of the contamination of oysters with the pink yeast occurs during the process of handling in the oyster house. The shell pile of the opening house offers the yeast a favorable place to grow, and when the shells are later deposited on the oyster beds they distribute the yeasts in the water.

To prevent the infection of opened oysters by the yeast, the house and utensils should be washed occasionally through the opening season with a 1 to 2500 formaldehyde solution (formalin 1 to 1000).

PURIFICATION OF BENZOIC ACID BY FRACTIONAL CONDENSATION.[1]

By Max Phillips and H. D. Gibbs.

[ABSTRACT.]

BENZOIC ACID, made by the chlorination of toluene, is contaminated with small amounts of compounds chlorinated in the ring, the presence of which is most objectionable from the physiological point of view when benzoic acid is used in food products. While it is very difficult to remove these compounds by the ordinary methods of purification, benzoic acid practically free from chloro-derivatives was obtained in the Bureau of Chemistry by the use of a special apparatus. This apparatus consisted of a vessel in which the crude benzoic acid was placed. The vessel was immersed in an oil bath kept at a definite temperature. A blast of hot air was passed into the crude benzoic acid and the

[1] Published in *J. Ind. Eng. Chem.*, 12, 277 (1920).

vapors coming off were conducted through a series of chambers, maintained at different temperatures. The least volatile chloro-derivatives separated out in the hotter chambers, whereas the more volatile benzoic acid collected in the colder chambers.

SOME ASPECTS OF THE BEHAVIOR OF CHARCOAL WITH RESPECT TO CHLORINE.[1]

By G. S. Bohart and E. Q. Adams.

[ABSTRACT.]

THIS investigation was undertaken to determine the cause of discrepancies between results obtained by different laboratories for the chlorine capacity of the same charcoals. To study the effect of temperature and humidity of the air stream with which the chlorine was diluted (usually 1 : 1000), mixtures of known air, chlorine, and moisture content were passed through the charcoal which was held in a glass chamber in a constant temperature bath. The chlorine and hydrochloric acid in the outgoing gas were determined from time to time.

In the particular series of charcoals studied, the variation in chlorine-absorbing power between different charcoals was greater than would result from any attainable variation in humidity, and the order of the charcoals with respect to absorptive power is not the same as that with respect to apparent density.

The duration of complete chlorine absorption (1) increases more rapidly than the thickness of the layer of charcoal, (2) passes through a minimum at a temperature between 0° and 12.5°, and (3) at a humidity in the neighborhood of 50 per cent., and (4) is diminished by increasing the flow of air, the rate of supply of chlorine remaining constant. Reductions in pressure up to two feet of water (barometric pressured down to 71 cm. mercury) has little or no effect.

For the charcoals studied: Below 12.5° chlorine appeared beyond the charcoal before hydrogen chlorid; above 12.5° hydrogen chlorid before chlorine, and the chlorine capacity of the charcoal was increased by one exposure to chlorine followed by heating in vacuo to dull redness.

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[1] Published in *J. Am. Chem. Soc.*, **42**, 523-44 (1920).

Borax as a Plant Poison. (*Department. Cir. 84, U. S. Dept. of Agriculture.*)—The cessation of potash imports upon the outbreak of the war gave great impetus to search for domestic sources of the substance. Current topic notes in recent issues of this JOURNAL have furnished some of the interesting data on these new industries. Among the sources operated on a rather large scale was that of Searles Lake, California, from which many tons were taken. In 1917 injurious effects were produced by some fertilizers of domestic manufacture and it was found that borax was the cause of this. Investigations were undertaken, and in 1918 Professor Conner of the Indiana Agricultural Experiment Station published a report which attracted considerable attention, as it showed that very small amounts of borax can produce poisonous effects on maize. This seems to be the first record of such action, and of the occurrence of borax in appreciable amounts in a commercial fertilizer. Conner's conclusion was that a fertilizer containing 2 per cent. of borax in the proportion of 100 pounds per acre will cause damage to maize. The United States Department of Agriculture began in 1919 experiments with Searles Lake potash, which was found to contain 6.25 per cent. of $Na_2B_4O_7$. This potash was used in complete fertilizers in such proportion as to give from 2 to 8 per cent. of K_2O, and was compared with potash from other sources. The experiments were carried out with potatoes in the northern and some southern states and with cotton in other states. While these experiments were in progress, complaints were received in large numbers from different districts stating that great injury was being done by potash fertilizers. Investigations in these districts showed that in all cases borax was present. The damage was greatest when the fertilizer had been drilled in with the seed, and more severe when soil and climatic conditions were such as to cause the fertilizer to remain long in contact with the seed or the recently sprouted form. The greatest damage was done to germination. In the case of the potato the affected plants showed characteristic conditions which cannot be mistaken for any form of disease and which are fully described in the circular. It is not thought likely that permanent damage has been done to fields thus poisoned, as rainfall among other conditions will gradually remove the borax, but if fertilizers containing this substance continue in use, it will be incumbent upon those engaged in fertilizer investigation to determine the possible cumulative effect. The quantity of borax sufficient to produce decided toxic effects is small compared with well-known poisons such as copper and arsenic. The Searles Lake company is now turning out potash salts with less than one-half of one per cent. of borax.

H. L.

NOTES FROM THE U. S. BUREAU OF MINES *

BLOW HOLES, POROSITY AND UNSOUNDNESS IN ALUMINUM ALLOY CASTINGS.

By Robert J. Anderson.

It is impossible to compile a code of directions which a melter can follow implicitly and obtain 100 per cent. of sound castings. The main conclusions that can be drawn from experimental study are:

1. The higher the pouring temperature the greater the number of blowholes and the more unsound the casting.

2. The higher the temperature to which the charge is heated the more unsound the castings are, regardless of the pouring temperature.

3. The longer any melt is held in the furnace the more unsound the castings are, regardless of the temperature of heating and pouring.

All possible combinations of these three may be obtained, ranging from the worst result where pouring is done at a high temperature after the charge has been held a long time in the furnace at a high temperature, to the best where pouring is done at a low temperature from a charge held the minimum time after it has melted. There is no evidence to justify a belief that unsound castings result from too low a pouring temperature. The best results will be obtained through a close supervision of melting and pouring, together with a study of the appropriate correlation between the molding floor and the furnace room. It will be best to have the molding floor waiting for metal rather than the furnace room waiting for molds. Close pyrometric control is also presupposed. The details of experimental investigations on which these conclusions are based are given in Technical Paper 241 of the Bureau of Mines.

* Communicated by the Director.

MINOR NOTES

Gases in Tunnels.—In connection with the investigation of automobile exhaust gases in vehicular tunnels, which is being made at the Pittsburgh station in coöperation with the New York and New Jersey Tunnel Commission, a test made on a roadster with different carburetor settings while running 15 miles per hour uphill with three passengers, showed that the carbon monoxide produced at 60°F. ranged from 2 per cent. at 1¼ turns of the needle valve to 11.6 per cent. carbon monoxide at 1¾ turns of the needle valve. This corresponded to 13.9 and 8.73 miles per gallon of gasoline respectively. The car did not exhibit the necessary flexibility at one turn of the needle valve, which gave 1.2 per cent. carbon monoxide and 14.9 miles per gallon, the air on the carburetor being choked one-half. Slight changes in the adjustment of the carburetor affect the composition of the exhaust gases very materially, and greatly affect the mileage per gallon of gasoline consumed.

Evaporation of Oil.—A study of evaporation losses of oil in storage and transportation in the mid continent field has been completed and is being prepared for publication. The bulletin will point out clearly the loss in quantity of crude oil and gasoline and in dollars and cents, giving instances of just where these losses occur under the ordinary methods of handling the oil from the well to the refinery.

Petroleum from Oil Sands.—A study of problems relating to increased recovery of petroleum from oil sands has been started at the Bartlesville station of the Bureau.

Marine Boiler Tests.—The boiler tests made for the Emergency Fleet Corporation at Erie, Pa., have been completed. These tests indicated that relatively simple modifications of the design of marine boilers would enable six tons of coal to do the work of seven.

Graphite for Crucibles.—A study of the use of American Graphites in Crucible making by Dr. Reinhardt Thiessen, of the Pittsburgh Station, indicates that American graphites are composed of innumberable very thin plates. These plates are grouped into natural orders, by means of natural cleavage planes. These orders may conveniently, though perhaps not strictly, be classified as primary, secondary, tertiary and quarternary, each

order being determined by primary, secondary, tertiary and quarternary cleavage planes.

The flakes as they are found in the rock contain one or more cleavage planes along which the several plates are held together very loosely, and through a slight agitation or effort they may divide into two or more distinct flakes. This would constitute the secondary groups. Each of the secondary groups in turn contain one or more, usually several, natural cleavage planes, along which the plates hold together relatively loosely, but more firmly than the primary, along which they may be separated or loosened up by mechanical means, into tertiary groups of plates. At a higher magnification of a cross-section of the flakes, it is found that the tertiary groups again contain cleavage planes, tertiary planes, dividing them in turn with quarternary laminations. These orders of laminations are so thin that they can not be separated by mechanical means. The quarternary laminations are in the neighborhood of one micron in thickness.

In puffed graphite, however, they have been separated. By transforming graphite into graphitic acid, it is shown that the quarternary laminæ consist further of a series of sublaminations. The ultimate plates are of submicroscopic thickness, probably in the neighborhood of 50 to 150 millicrons.

The various methods employed to separate the graphite from the gangue divides the original flakes more or less into thinner flakes along the primary and secondary cleavage planes, or loosens them up along these planes as well as along the tertiary planes. This results in a fluffy, incoherent flake.

Photosensitiveness of Thallium Chloride.—Carl Renz (*Helv. Chim. Acta.*, 1919, vol. ii, 704) describes a series of experiments showing that thallium chloride (TlCl) is affected by light, indicated by color changes in the order gray brown, dark gray brown, and brownish black. The changes are largely molecular, but some subchloride is also formed. Hydrochloric acid even in minute amounts prevents the action, as also do sulphuric and nitric acids. Ammonia, ethylamin and a large number of organic liquids and many inorganic salts act as sensitizers. The sensitiveness of the salt is influenced by the method of preparation. Specimens prepared by precipitation of thallium solution with metallic chlorides are much more sensitive than that prepared by precipitation with hydrochloric acid, even when this is thoroughly washed.

H. L.

The Height of the Aurora Borealis as Determined at the Haldde Observatory, Norway. L. VEGARD and O. KROGNES. (*Annalen der Physik*, vol. li, 1916.)—If the aurora is photographed at the same time from two stations it is possible, as Stoermer has shown, to get the height of any characteristic feature appearing on both plates from its two different positions with respect to the stars. The stations must have telephonic connection. Those by means of which the greatest number of determinations have been made are 26.3 km. apart.

The upper boundaries of the auroras vary from 100 to 330 km. above the earth, and are usually indistinct. They are highest for rays and lowest for arches. The lower boundaries are clearly defined. No less than 1920 measurements of height are divided into six groups, according to the forms assumed by the aurora and the average height is calculated for each class. It is remarkable how closely these average heights of the lower boundaries are grouped together between 104 and 114 km., the general average being 108.2 km. When curves are formed by plotting the number of lower limits at a height against the height it is found that there are two maxima corresponding to heights of 100 and 106 km. respectively, which persist in showing themselves even when results from different pairs of stations are used for the curve.

G. F. S.

A New Method of Determining the Solar Constant of Radiation. C. G. ABBOT. (*Proc. of the National Academy of Sciences*, January, 1920.)—The method hitherto employed, that of Langley, consisted in measuring the intensity of solar radiation at the earth's surface and then of determining the transparency of the atmosphere for all wave-lengths by the spectro-bolometer. The latter part required several hours during which the atmosphere should not have changed. At the Calama Smithsonian Station a new and faster method has been developed. The brighter the sky is and the larger the amount of water vapor in the air, the less is the atmospheric transmission. Quantities can be measured which are determined by brightness of sky and by content of water vapor. A function of these two quantities is formed and is plotted against air transmission coefficients, all the quantities involved being related to similar atmospheric conditions. It takes only ten minutes to make all the measurements needed to determine the function mentioned. When it has been determined, the transmission coefficient can be read off. Several radiation determinations can be completed in a single day, and besides this the new method can be applied on a greater number of days than the old one could.

G. F. S.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, April 21, 1920.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 21, 1920.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 7.

The following gentlemen, nominated by the Board of Managers, were unanimously elected to Honorary Membership: Sir Charles Algernon Parsons, K.C.B., C.B., M.A., LL.D., D.Sc., F.R.S., and Prof. Svante August Arrhenius, Ph.D., M.D., D.Sc., LL.D.

Reports were presented by the Committee on Library and the Committee on Science and the Arts.

The paper of the evening on "The Design of War Vessels as Affected by the World War" was presented by Rear Admiral David Watson Taylor, Chief Constructor, U. S. N., Chief of Bureau of Construction and Repair, Navy Department, Washington, D. C. A description was given of the various types of vessels existing at the beginning of the war and the improvements and changes made or shown to be desirable during the progress of the war. The question of new types of war vessels growing out of war experience was also discussed. Lantern slides of various classes of war vessels of several countries were shown.

After a vote of thanks to the speaker the meeting adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, April 7, 1920.)

HALL OF THE INSTITUTE,
PHILADELPHIA, April 7, 1920.

MR. CHARLES PENROSE *in the Chair.*

On the recommendation of the Sub-Committee on Literature, the following awards were made for papers in the JOURNAL, 1919:

No. 2757: The Edward Longstreth Medal of Merit to Mr. M. Luckiesh, of the Nela Research Laboratory, Nela Park, Cleveland, Ohio, for his paper entitled: "The Visibility of Airplanes," which appeared in the issues of the JOURNAL OF THE FRANKLIN INSTITUTE for March and April, 1919.

No. 2758: The Certificate of Merit to Messrs. David Landau and Percy H. Parr for their series of papers on "A New Theory of Plate Springs," which appeared in the JOURNAL OF THE FRANKLIN INSTITUTE for April, 1918, December, 1918, and February, 1919.

The following reports were presented for first reading:
No. 2746: Method of Machining Propeller Blades.
Mr. Charles W. Masland, Chairman.
No. 2747: Concealing Coloration.
Dr. Thomas D. Cope, Chairman.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A joint meeting of the Section and the Physics Club of Philadelphia was held in the Hall of the Institute on Thursday, April 1, at 8 o'clock, P.M. Dr. Thomas D. Cope in the Chair. The minutes of the previous meeting were approved as read.

Charles E. Mendenhall, Ph.D., Professor of Physics in the University of Wisconsin, delivered a lecture on "Aeronautical Instruments." A description was given of the standard instruments used for the determination of height, speed and engine performance, and for the navigation of the airplane. Mention was also made of instruments which are being developed for these purposes. The lecture was illustrated with lantern slides.

The paper was discussed; a rising vote of thanks was extended to Doctor Mendenhall, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Electrical Section.—A joint meeting of the Section and the Philadelphia Section, American Institute of Electrical Engineers, was held on Thursday evening, April 8, 1920. Mr. W. C. L. Eglin and Mr. W. F. James presided jointly.

The paper of the evening on "Electric Welding as Applied to Shipbuilding" was presented by Comfort A. Adams, S.B., E.E., Dean of the Harvard Engineering School, Harvard University, Cambridge, Mass. The speaker reviewed the theory and practice of electric welding, including resistance welding, spot welding, and arc welding. The strength and other physical properties of electric welds were considered, as well as the application of electric welding in the industries. An account was given of past experience in the use of electric welding in shipbuilding, with some indications of its future prospects. Attention was also given to the design and construction of welded ships. The subject was illustrated by lantern slides.

After a vote of thanks to the speaker the meeting adjourned.

ALFRED RIGLING,
Acting Secretary.

Mining and Metallurgical Section.—A joint meeting of the Section and the Philadelphia Section of the American Chemical Society was held in the Hall of the Institute on Thursday evening, April 15, at 8 o'clock, with

Prof. Alexander E. Outerbridge, Jr., in the Chair. The minutes of the previous meeting were approved as published.

D. A. Lyon, Ph.D., Bureau of Mines, U. S. Department of the Interior, Washington, D. C., delivered a lecture on "Recent Progress in the Metallurgy of Non-ferrous Metals." An account was given of recent advances in the winning of gold, silver, copper, lead, and zinc from their ores. The paper was discussed by Doctors Keller and Lyon, Professor Outerbridge and Mr. Clamer. On motion of Mr. Clamer, a vote of thanks was extended to Doctor Lyon for his valuable communication. The meeting then adjourned.

JOSEPH S. HEPBURN,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, April 14, 1920.)

RESIDENT.

MR. SAMUEL G. DIXON, 2D, Marine Engineer, Montgomery Avenue, Ardmore, Pennsylvania.

DR. FRANKLIN G. HAWKSWORTH, Dentist, 314 N. 13th Street, Philadelphia, Pennsylvania.

MR. WALTER E. HOLLAND, Research Engineer, Philadelphia Storage Battery Company, Ontario and C Streets, Philadelphia, Pennsylvania.

MR. ROLAND G. PORTER, Gas Engineer, Swarthmore, Pennsylvania.

ASSOCIATE.

MR. FELIPE T. ADRIANO, Industrial Chemist, 102 N. Orchard Street, Madison, Wisconsin.

MR. F. MACMURPHY, Student, 301 West 108th Street, New York City, New York.

MR. SAMUEL N. MORRISON, Manufacturer of Oil Dressings, 143 W. Lehigh Avenue, Philadelphia, Pennsylvania.

CHANGES OF ADDRESS.

MR. A. I. APPLEBAUM, P. O. Box 808, Trenton, New Jersey.

MR. J. VAUGHAN BOSTWICK, Roxborough, Philadelphia, Pennsylvania.

DR. M. E. COOLEY, Engineering Building, University of Michigan, Ann Arbor, Michigan.

MR. EDWIN FRANK, 5233 "A" Wissahickon Avenue, Germantown, Philadelphia, Pennsylvania.

MR. G. L. KOTHNY, Woodland Road, Strafford, Pennsylvania.

MR. H. H. MAXFIELD, General Superintendent, Motive Power, Pennsylvania System, Central Region, Pennsylvania Station, Pittsburgh, Pennsylvania.

MR. W. HEYWARD MYERS, Haverford, Pennsylvania.

PROF. C. C. THOMAS, Johns Hopkins University, Baltimore, Maryland.

DR. J. A. L. WADDELL, 35 Nassau Street, New York City, New York.

MR. J. R. WATKINS, 817 Oakbridge Avenue, Madison, Wisconsin.

NECROLOGY.

Carrol M. Bunting was born at Darby, Pa., on September 15, 1871, and died in Philadelphia on March 4, 1920.

He was educated at the Darby Friends School, the Philadelphia Public Schools and Bryant and Stratton's Business College.

In 1887 he became a clerk in the Freight Office at Philadelphia for the Chicago, Rock Island & Pacific Railroad Company. He then entered the office of the Through Freight Agent of the Philadelphia & Reading Railway, and later served in the Philadelphia Freight Office of the Northern Pacific and Wisconsin Central Company. In 1890 he became Secretary to the Third Vice President of the Pennsylvania Railroad Company. Seven years later he was made Chief Clerk to the First Vice President and in 1906 became assistant to the same official. He was appointed Assistant Comptroller on March 24, 1909, and in June, 1910, was made Comptroller.

Shortly after the United States entered the World War, Colonel Bunting obtained leave of absence and served as business manager of the Transportation Corps, American Expeditionary Forces. He was also a member of the staff of Brigadier General W. W. Atterbury, Director General of Transportation. He returned from France early in 1919, and had been in poor health since that time.

Colonel Bunting became a member of the Institute September 11, 1912.

Mr. John A. Brown, Jr., Real Estate Trust Building, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

American Iron and Steel Institute.—Year Book. 1910, 1912–1918.

Blocksidge, E. W.—Ship's Boats; their Qualities, Construction, Equipment and Launching Appliances. 1920.

Boulnois, H. P.—Modern Roads. 1919.

Burghardt, H. D.—The Lathe, Bench Work, and Work at the Forge. 1919.

Hovestadt, H.—Jena Glass and Its Scientific and Industrial Applications. 1902.

James, H. D.—Controllers for Electric Motors. 1919.

Judge, A. W.—Elementary Principles of Aeroplane Design and Construction. 1919.

Kleeman, R. D.—Kinetic Theory of Gases and Liquids. 1920.

Lauer, Henri, and Brown, H. L.—Radio Engineering Principles. 1920.

McCoy, H. W., and Terry, E. M.—Introduction to General Chemistry. 1920.

Pender, Harold.—Electricity and Magnetism for Engineers. 2 vols. 1918–19.

Pippard, A. J. S., and Pritchard, J. L.—Aeroplane Structures. 1919.

Simmonds, Charles.—Alcohol; Its Production, Properties, Chemistry, and Industrial Applications. 1919.

Stieglitz, Julius.—Elements of Qualitative Chemical Analysis. Vol. 1. 1919.

Wade, C. F.—Efficient Boiler Management. 1919.

GIFTS.

Air Reduction Sales Company, Catalogue of Airco Regulators and Gauges. No date. (From the Company.)

Akerlund and Semmes, Inc., Catalogue of the Akerlund Gas Producers. New York, N. Y., 1920. (From the Company.)

Alfred University, Catalogue for 1919–1920. Alfred, N. Y., 1920. (From the University.)

Allen Cone Company, Bulletins Nos. 12, 13 and 14. El Paso, Texas. No date. (From the Company.)

American Society of Civil Engineers, Transactions Vol. liv, Part B. New York, 1905. (From Mr. W. Copeland Furber.)

Beaudry and Company, Inc., Catalogue of Beaudry Hammers. Boston, Mass., no date. (From the Company.)

Bilton Machine Tool Company, Catalogue No. 1. Bridgeport, Conn., no date. (From the Company.)

British India, Annual Return of Statistics Relating to Forest Administration for the Year 1917–1918. Simla, India, 1919. (From the Forest Administration.)

Canada Department of Customs, Shipping Report for the Year Ending March 31, 1919. Ottawa. (From the Department.)

Case School of Applied Science, Catalogue 1919–1920. Cleveland, Ohio, 1920. (From the School.)

Celluloid Zapon Company, Catalogue of Lacquers and Lacquer Enamels. New York, N. Y., 1919. (From the Company.)

Clarkson College of Technology, Bulletin No. 1. Potsdam, N. Y., 1920. (From the College.)

Climax Molybdenum Company, Catalogue of Molybdenum Commercial Steels. New York, N. Y., 1919. (From the Company.)

Colorado School of Mines, Catalogue No. 1. Golden, Colorado, 1920. (From the School.)

Columbus McKinnon Chain Company, Booklet of Chains. Columbus, Ohio, no date. (From the Company.)

Connecticut Society of Civil Engineers, Proceedings for 1916 and 1919. New Haven, Conn., 1916–1919. (From Prof. L. M. Haupt.)

De Pere-Burton Company, Catalogue of Water Tube Boilers. Milwaukee, Wis., no date. (From the Company.)

Giant Concrete Pile Company, Inc., Catalogue, A Precast Pile. New York, N. Y., no date. (From the Company.)

Hickey and Schneider, Inc., Bulletin No. 15. Elizabeth, N. J., 1920. (From the Company.)

Holz and Company, Inc, Bulletin No. 22–23. New York, N. Y., 1920. (From the Company.)

Illinois Society of Engineers, Thirty-third Annual Report for 1918. Wheaton, Ill., 1918. (From Prof. L. M. Haupt.)

Illinois Stoker Company, Catalogue "L." Alton, Illinois, no date. (From the Company.)

Indiana Engineering Society, Proceedings for 1916–1917. Indianapolis, Ind., 1917. (From the Society.)

Iron and Steel Institute, Journal Vol. C, 1919. London, England, 1919. (From the Institute.)

Laclede-Christy, Booklet, Boiler Capacities with Chain Grates. St. Louis, Mo., 1920. (From the Company.)

Lafayette Tool and Equipment Company, Catalogue of the Lafayette Universal Grinder. Philadelphia, Pa., no date. (From the Company.)

Leeds and Northrup Company, Bulletin No. 726. Philadelphia, Pa., 1919. (From the Company.)

Leetonia Tool Company, Catalogue No. 3. Leetonia, Ohio, no date. (From the Company.)

Little Falls Board of Public Works, Twenty-fifth Annual Report for 1919. Little Falls, N. Y., 1919. (From the Board.)

Massachusetts State Department of Health, Third Annual Report 1917. Boston, 1918. (From the Department.)

Modern Tool Company, Catalogue of Grinding Machines. Erie, Pa., no date. (From the Company.)

Norwalk Iron Works Company, Bulletin No. 6. South Norwalk, Conn., no date. (From the Company.)

Nova Scotia Department of Public Works and Mines, Annual Report on the Mines, 1919. Halifax, 1920. (From the Department.)

Ontario Bureau of Mines, Twenty-eighth Annual Report 1919. Toronto, Canada, 1919. (From the Bureau.)

Parkesburg Iron Company, A History of the Boiler Tube of Greatest Ultimate Economy. Parkesburg, Pa., 1919. (From the Company.)

Pedrick Tool and Machine Company, Catalogue of Pedrick Machine Tools. Philadelphia, Pa., 1920. (From the Company.)

Pennsylvania Commonwealth, Annual Report of the Bureau of Railways for 1917. Harrisburg, Pa. 1919. (From the Commonwealth.)

Pennsylvania Commonwealth, Report of the Auditor General for the Year 1917. Harrisburg, Penna., 1919. (From the Commonwealth.)

Pennsylvania State College, Annual Report for the Year 1915–1916. Harrisburg, Pa., 1918. (From the College.)

Pennsylvania Water Supply Commission, Reports for 1910 and 1913. Harrisburg, Pa., 1914. (From Mr. W. Copeland Furber.)

Philadelphia Rapid Transit Company, Annual Report to the Stockholders 1919. Philadelphia, Pa., 1920. (From the Company.)

Rawson Electrical Instrument Company, Bulletin No. 1. Cambridge, Mass., 1919. (From the Company.)

Reed Small Tool Works, Catalogue No. 4. Worcester, Mass., 1919. (From the Works.)

Ric-Wil Company, Bulletins Nos. 1 to 3 inclusive. Cleveland, Ohio, 1919. (From the Company.)

Saco-Lowell Shops, Catalogue of Cotton Mill Equipment. Boston, Mass., 1920. (From the Shops.)

Sanford Riley Stoker Company, Catalogue of Riley Under-feed Stokers. Worcester, Mass., 1920. (From the Company.)

Sharp Rotary Ash Receiver Company, Inc., Booklet, "Monolog." Binghamton, N. Y., 1920. (From the Company.)

Standard Machinery Company, Catalogue of Power Presses. Auburn, R. I., 1920. (From the Company.)

Stevens, Frederic B., Catalogue No. 8. Detroit, Mich., 1919. (From F. B. Stevens.)

Under-Feed Stoker Company of America, Catalogue of Industrial Heating Furnaces Equipped with Jones Under-Feed Mechanical Stokers. Detroit, Mich., 1920. (From the Company.)

Union Draft Gear Company, Booklet, Force and Its Applied Principles. Chicago, Ill., 1919. (From the Company.)

University of Maine, Catalogue 1919–1920. Orono, Maine, 1919. (From the University.)

U. S. Navy Paymaster General, Annual Report for the Year 1919. Washington, D. C. (From the Paymaster General.)

War Department, Annual Report of the Chief Signal Officer for 1919. Washington, D. C., 1919. (From the Department.)

Washburn and Granger, Inc., Catalogue No. 9. New York, N. Y., 1920. (From the Company.)

Western Australia Department of Mines, Report for the Year 1918. Perth, Australia, 1919. (From the Department.)

Yale University, Report of the President 1918–1919. New Haven, Conn., 1919. (From the University.)

BOOK NOTICES.

DATA OF GEOCHEMISTRY. United States Geological Survey, Bulletin 695. By Frank Wigglesworth Clarke. 4th edition. 773 pages and index, 8vo. Washington, Government Printing Office, 1920.

This work comprehends an elaborate study of the materials constituting the earth as included in human experience; that is, the lithosphere and the atmosphere. A vast amount of information concerning the composition of rocks, waters and gases is presented in a readable and at the same time strictly scientific form. The literature has been searched thoroughly and with great care, and it is really astonishing to those who have not followed the special field to which the work is devoted to see the extent of the researches already carried out. There is a somewhat romantic feature of the essay, inasmuch as discussions are given concerning the age of the earth's crust, the origin of the atmosphere and the source of the great mass of carbon now locked up in the rocks which are so marked a feature of the crust as we know it. As might be expected, the discussions on these subjects do not lead to any positive result, although some of the promulgators of special views are quite convinced of the reliability of their conclusions.

Special note should be given to Doctor Clarke's method of presenting the composition of waters. Discarding the usual methods of uniting the several positive and negative ions into salts according to the arbitrary methods long in vogue, he recalculates the data into percentage of the ions, using the residue after ignition as the total fixed solids. It is, of course, an advantage to get rid of the so-called "loss on ignition," which

is so common in statements of water analysis, for the figure has neither practical nor theoretical value, but it is an open question whether the residue dried at a moderate temperature will not in many cases be a safer guide. The figure for the fixed solids is stated as "salinity," a word that may be not wholly satisfactory, as it seems to suggest the content of chlorides. Doctor Clarke's method of presenting the data of water analysis has the advantage of enabling quick and convenient comparison of waters of the same type and showing vividly the contrast between waters of different types.

It will be probably a long while before the commercial analyst will be able to make a statement of water analysis on the basis of the unassociated ions, for his clients always want a presentation that will show some of the specific actions of the sample. Even many scientific workers hesitate to set down Fe^{III} or SiO_3.

HENRY LEFFMANN.

AIDS IN THE COMMERCIAL ANALYSIS OF OILS, FATS AND THEIR COMMERCIAL PRODUCTS. By George Fenwick Pickering. viii—129 pages and index. 8vo. Philadelphia, J. B. Lippincott Company, 1917.

Not much new matter can be expected in a book of this size on a topic which has been so extensively exploited as that of the fats and oils, for the existing literature is immense. The work contains a great deal of information compactly presented, especially in tabular form. The methods chosen are mostly so-called "works methods," and do not claim such a degree of accuracy as is found in many departments of inorganic analysis. The author states that all the figures given are published for the first time. Mr. Pickering's position as a research assistant to the late Doctor Lewkowitsch is a guarantee that he has had large experience in careful work and is familiar with the field to which the book is devoted. The nomenclature is mostly conservatively English, and the determination of the volatile acids is given only by the alcohol-potassium hydroxide method, no mention being made of the glycerol-soda procedure, which is now official in France, Germany and several other leading European nations.

HENRY LEFFMANN.

THE PHOTOGRAPHIC RESEARCHES OF FERDINAND HURTER AND VERO C. DRIFFIELD, being a reprint of their published papers, together with a review of their earlier work and a bibliography of their later work. Edited by W. B. Ferguson, K.C., M.A. (Oxon.), F.I.C. Hon. F.R.P.S. Small folio, 366 pages, indexes, and numerous illustrations. London, The Royal Photographic Society of Great Britain, 1920.

The names of Hurter and Driffield are familiar to all photographers, and the Royal Photographic Society has done them just honor by thus presenting in full many of their papers and furnishing a bibliography for the rest. The apparatus and manuscripts are now in the custody of that society. A list of these is given, and shows a very large and varied collection.

Frederick Hurter was born in 1844 at Schaffhausen in Switzerland, and after studies at Zurich went to Heidelburg, where he studied under

Bunsen, Kirchoff and Helmholtz, and in 1866 he took the degree of Ph.D. "Summa cum laude." He spent the last thirty-one years of his life in England, for which he had a definite preference. He began his work there as an assistant to Mr. Deacon in the alkali works of Gaskell, Deacon & Co.

Vero C. Driffield was born in Lancashire. He was early interested in photography, but also entered into the service of Gaskell, Deacon & Co., as an engineer, and there met Doctor Hurter. It was, however, a mutual passion for music that led to the intimacy.

The book contains many data of great interest to photographers. Among the most comprehensive of the contributions is that published in 1898 on "The Latent Image and Its Devlopment," a joint contribution.

The book is excellently printed and will furnish much attractive reading to all interested in photochemistry.

HENRY LEFFMANN.

UTILISATION DES ALGUES MARINES. Par Camille Sauvageau. Professor in the Faculty of Science, Bordeaux. 12mo., 356 pages, bibliography, contents, indexes and 26 illustrations. Paris, Gaston Doin. 9 francs.

This work is one of a series designated "Encyclopédie Scientifique," which has a wide scope, a list of forty volumes being appended to the present publication. Its form is very pleasing, being printed on good paper with clear type, of a more agreeable face than that often used in French books. The coastal districts of Brittany and Normandy and some adjacent islands owe a good deal of prosperity to the marine algæ, which are used as fertilizers. In former years, the material was burned and sodium salts extracted; later potassium and iodine were the principal yields. During the late war proposals were made for the use of these plants as fodder, and even as human food, and the French Government through one of its bureaus requested M. Sauvageau to investigate the subject. His results, supplemented by his wide information on the botany and biology of the algæ, are embodied in the book. A great deal of information is contained in it, among which are to be noted the government regulations for the harvesting of the more important species, descriptions of the American methods of gathering, data regarding the composition and the uses that have been made as food for men and domestic animals. The illustrations are neatly drawn and the book will be useful to the cryptogamist, biologist and economist.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 50. Calculation for low pressure indicator diagrams. Preprint from Fourth Annual Report. 13 pages, diagrams, quarto. Washington, Government Printing Office, 1920.

This report contains a theoretical study of the pressure variations in an internal combustion engine cylinder during the low pressure part of the cycle. It is assumed that the rate of flow of air and burnt gas through the inlet and exhaust valves, respectively, may be calculated from the manifold pressures, the cylinder pressure, and the valve clear openings

by the ordinary formulas for steady flow through an orifice with the aid of determinable coefficients of efflux. Differential equations for the rate of change of the pressure in the cylinder during the exhaust and suction strokes are set up. A method for the graphical integration of these equations is indicated. Efflux coefficients taken from the experiments of Lewis and Nutting are used in the application of the theory to a typical motor, and a theoretical low pressure indicator diagram for this motor is obtained.

Report No. 51. Spark Plug Defects and Tests. Preprint from Fifth Annual Report. 32 pages, illustrations, quarto. Washington, Government Printing Office, 1920. A discussion of the various causes of failure of spark plugs, with indications for their identification and possible remedies. The results of gas leakage measurements on several hundred plugs are given and the results tabulated on a basis of design, material, etc. The final chapter describes methods worked out for testing spark plugs in the laboratory for (1) electrical conductivity when hot, (2) resistance to thermal cracking, (3) gas tightness, (4) resistance to mechanical shock, (5) dielectric strength, (6) engine test.

Report No. 61. Head Resistance due to Radiators. Preprint from Fifth Annual Report. 22 pages, illustrations, quarto. Washington, Government Printing Office, 1920. The report gives detailed descriptions of apparatus, experimental methods, and methods of computation used in determining (*a*) head resistance, and (*b*) power absorbed due to head resistance and weight, for radiators in "unobstructed" positions on the airplane. Results obtained on 24 types are shown in tables and curves. Effects of yawing the radiator are shown for four representative types. A brief discussion of the importance of head resistance is given.

Curves show measured head resistance of a model fuselage under three conditions: (1) with stream-lined nose, (2) with flat nose, and (3) with nose radiator. Three widely different types of radiators were used.

A method of enclosing a radiator in a stream-line casing is described, but results show that, while head resistance may be reduced by the use of the casing, air flow through the core and heat transfer are decreased to such an extent as to lower the efficiency.

R.

PUBLICATIONS RECEIVED.

Royal Photographic Society of Great Britain: A memorial volume containing an account of the photographic researches of Ferdinand Hurter and Vero C. Driffield, being a reprint of their published papers, together with a history of their early work and a bibliography of later work on the same subject. Edited by W. B. Ferguson. 374 pages, illustrations, portraits, quarto. London, Royal Photographic Society of Great Britain, 1920. Price, 25 shillings.

Utilisation des algues marines, par Camille Sauvageau. Encyclopédie Scientifique. 394 pages, illustrations, 12mo. Paris, Octave Doin, 1920. Price, in cloth, 9 francs.

U. S. Bureau of Mines: Bulletin 95, A Glossary of the Mining and Min-

eral Industry, by Albert H. Fay. 754 pages, 8vo. Technical Paper 250, Metal-mine Accounting, by C. B. Holmes. 63 pages, 8vo. Technical Paper 252, Metal-mine Accidents in the United States During the Calendar Year 1918 (with supplemental labor and accident tables for the years 1911 to 1918, inclusive), compiled by Albert H. Fay. 113 pages, 8vo. Technical Paper 256, Accidents at Metallurgical Works in the United States During the Calendar Year 1918. Compiled by Albert H. Fay. 23 pages, 8vo. Washington, Government Printing Office, 1920.

U. S. Department of Agriculture, Weather Bureau: Daily River Stages at River Gauge Stations on the Principal Rivers of the United States. Volume XVI, for the year 1918, by Alfred J. Henry, meteorologist. 288 pages, quarto. Washington, Government Printing Office, 1919.

The Philadelphia Museums, The Commercial Museums. Hand-books to the Exhibits. No. 3, The Peat Exhibit. 56 pages, illustrations, 8vo. Philadelphia, The Museums, 1920. Price, 25 cents.

University of Illinois Convocation: The Watt Centenary and the College of Engineering Open House. 20 pages, illustrations, portrait, diagram, 8vo. Urbana, University, 1920.

U. S. Department of Labor, Bureau of Labor Statistics: Prices and Cost of Living. From the Monthly Labor Review, March, 1920. 52 pages, 8vo. Washington, Government Printing Office, 1920.

Two Years of Faulty Taxation and the Results, by Otto H. Kahn. 52 pages, 12mo. No place, 1920.

Pacific or 4-6-2 Type of Locomotive. Educational Chart No. 12. 44 x 16½ inches. New York, Railway and Locomotive Engineering, 1920.

Present-Day Radiography. MAJOR G. W. C. KAYE. (*Electrician*, Feb. 6, 1920.)—X-rays have been found to penetrate no less than 5 mm. of lead and for the protection of the operator 3 mm. of this metal are desirable.

Flaws, blowholes, bad welds, blisters and concealed riveting all are detected by radiography. At present the practicable thicknesses which can be investigated are three inches for steel and twice as much for aluminium.

During the war much use was made of the X-rays in examining the wooden parts of aeroplanes, especially the laminated parts. This method of construction enabled smaller timber to be used but also increased the difficulties of detecting faults. By the X-rays, however, bad gluing, grub holes, knots and bad workmanship were laid bare.

An interesting suggestion is made that this method of investigation be applied to growing timber to detect defects, the presence of nails, axe heads and internal shakes filled with mineral deposits, such as phosphates in teak.

At the Röntgen Society Exhibition in London radiographs of Dutch pictures of about 1500 A.D. were displayed. In one case an alteration was shown which consisted in painting a portrait of the donor upon the picture of a monk. G. F. S.

CURRENT TOPICS.

A New Method of Analysis.—Wm. Roy Mott, Research Chemist for the National Carbon Company, presented at the recent meeting of the American Electrochemical Society (April 8–10, 1920) a description of a carefully worked out method of detecting the several elements by means of the characteristics of the electric arc-action on compounds of these elements. The process is an extension of the method of flame tests, which method, as is well known, finds special development in the spectroscope. Mott's apparatus is, however, much simpler than the spectroscope, and his procedure rapid and accurate. The following data are taken from an advance publication of the proceedings of the American Electrochemical Society. The essential apparatus consists of a carbon arc-lamp in a hood, so arranged as to project a magnified image upon a screen in a dark room. Usually a magnification of twenty diameters is satisfactory, but for a few very dim arcs a lower power is advisable. The lamp is trimmed with solid carbons about 13 mm. in diameter, such as are commonly used in closed arc lamps. A cup about 10 mm. in depth and diameter is drilled into the top of the lower carbon, which is usually connected with the positive pole. The average weight of the sample used is 0.5 grm. Mott operated the lamp at 25 amperes and 50 (arc) volts, from a 110-volt line.

The phenomena obtained are flame-tip color, sparks, smoke, odor, sequence of distillation, and especially the nature and color of the deposit on the poles. A special vapor luminescence, near positive crater, is characteristic of some elements; for instance, calcium gives a unique red The colors of the flame tip above the arc are tests for sodium, lithium, boron and copper. Iron produces a display of scintillating sparks from the negative carbon for several seconds after breaking the arc. Smoke is not as a rule a delicate test, but the emission of smoke from the hot upper tip on breaking the arc is a very delicate test for molybdenum, as Mott has not found a similar effect given by any other element. The odor aids in detecting arsenic, bromine, iodine and tungsten. The color and shape of the deposit on the upper carbon are excellent points for classification. It is obvious that the method affords a form of fractional distillation at high temperatures, and of great range from mercury which boils at 257.2° C. to tungsten which boils at about 6000° C.

The new methods of analysis, using the arc images, are simple, quick, delicate, automatic, semi-quantitative and comprehensive. Good tests are given later for sixty-five elements. Any of these can be quickly and easily identified in a few minutes in their ores, alloys, oxy-compounds or in small, very impure samples. The chief impuri-

ties are usually automatically discovered as the distillation proceeds. In mixtures of three metallic compounds—especially oxy-compounds—complete identification should be obtained in less than a quarter of an hour. The tests, so far developed, will identify on the average nine out of ten in unknown mixtures of any ten of these sixty-five elements. Very delicate tests (sensitive to 0.1 mg.) apply mostly to the uncommon, valuable, and refractory elements, which take so much time and skill to identify by the usual wet methods. In regard to halogen salts, the best procedure is to form oxy-compounds by alkali carbonate fusion, or other means. The tests as given apply directly to all ores, minerals, refractories, oxides, oxy-compounds, carbides, metals and alloys.

Future developments should lead to an extensive use of arc image analysis, as it supplements and aids all other means of analysis. It is much like a refined blow-pipe analysis in utilizing colored beads and deposits. It is like fire-assay in using metal bead separations. It is like spectrum analysis in using colored light. Finally, it is like micro-chemistry in utilizing magnified phenomena. These similarities explain its comprehensiveness and indicate a large field for further study.

H. L.

Coke Industry in 1919. (*U. S. Geological Survey Press Bulletin No. 442*, April, 1920.)—The outstanding features of the coke industry in 1919 were the great slump in demand that followed the armistice and a remarkable increase in the proportion of by-product coke as compared with beehive coke.

The output of by-product coke consequently exceeded that of beehive coke for the first time. In 1918 about 46 per cent. of the total coke made in the United States was produced in by-product ovens and 54 per cent. in beehive ovens. In 1919 the proportions were reversed, 56 per cent. coming from by-product and only 44 per cent. from beehive ovens. The year 1919 thus marked a turning point in the history of coke manufacture in the United States.

These figures are preliminary only and will be revised when the annual statistical canvass is completed.

The iron furnaces are the great customers of the coke industry. With the growth in the output of by-product ovens the beehive coke industry is likely to become more and more an auxiliary source of fuel, carrying the peak load in times of extreme activity and correspondingly restricted in times of depression.

The maximum capacity of the by-product plants has been estimated at 27,000,000 net tons of coke at the beginning of 1918, 33,700,000 tons at the beginning of 1919, and 39,500,000 tons at the beginning of 1920. These annual capacities are estimated on a basis of 100 per cent. operation. In actual practice, however, an average operation above 90 per cent. can not be assumed for the country as a whole, and the safer figure of 85 per cent. would appear better justi-

fied by experience. Under an operation of 85 per cent. the present capacity of the country would be about 33,600,000 tons. Completion of the plants now under construction may raise the capacity to approximately 43,300,000 tons, or 36,800,000 tons under an operation of 85 per cent.

Estimated according to the quantity of by-product coke produced in 1919—25,171,000 tons—the quantities of by-products recovered during the year amounted to 668,200,000 pounds of ammonium sulphate or equivalent, 251,000,000 gallons of tar, 84,800,000 gallons of crude light oil, and 367,700,000,000 cubic feet of gas.

Some Studies of Metals by Means of X-rays. S. NISHIKAWA and G. ASAHARA. (*Phys. Rev.*, January, 1920.)—A pencil of heterogeneous rays from a Coolidge tube was received upon a photographic plate after having traversed a thin sheet of metal. Rolled metal gave a blurred pattern, but each metal had its own pattern. When the metal was annealed a considerable change of pattern followed, definite spots replacing the blurred figures. Silver and tin gave changed patterns after being kept at room temperature for some time. The disappearance of strain can thus be followed. Rolled thallium gave a figure consisting of spots arranged along radii. When it was heated to 235° C. suddenly a new pattern made its appearance. This is retained during further heating. Upon cooling another abrupt change manifests itself at the same temperature, but the resulting pattern is not the same as the first.

G. F. S.

Science and Its Application to Marine Problems. J. C. MCLENNAN, O.B.E. (*Trans. Northeast Coast Institution of Engineers and Shipbuilders.*)—In this very comprehensive and interesting paper it is stated that Sir J. J. Thomson suggested and D. A. Keyes applied to the study of the propagation of pressures caused by explosions under water the phenomenon that certain crystals become charged with electricity when subjected to pressure. As the amount of the charge is directly proportional to the pressure, measurement of the amount of the pressure is possible, but the problem is not easy, since the time it takes to crush a submarine is only a few thousandths of a second, while the pressure may be of the order of 1000 pounds per square inch. To record pressure changes a beam of cathode rays was deflected in one direction by an alternating magnetic field and in a direction perpendicular to the first by the electric field set up by the charge developed on the crystal by the pressure wave. Changes taking place in one one hundred-thousandth of a second can thus be traced. Valuable conclusions relating to the best methods of laying out mine fields and employing depth charges have been drawn as a result of Curie's recondite discovery of piezo-electricity.

G. F. S.

Carbon Determination in Ferro-alloys.—C. J. ROTTMANN, Advance Sheets, *Amer. Electrochem. Soc.*, Thirty-seventh General Meeting, April 8–10, after pointing out the difficulties of correct determination of carbon in these alloys, describes construction of furnaces, absorption bulbs, and methods by which accuracy to 0.002 per cent. can be attained. Minute directions are given for taking the sample. The furnace is nichrome wound, and a thick-walled silica tube is to be used, as thin tubes become penetrable above 1200° C. The special form of the absorption bulb is figured, and is stated to be light, compact, and easily handled. A comparatively large amount of liquid may be used, thus allowing many runs without refilling. The test-analyses given with samples from Bureau of Standards are very satisfactory.

H. L.

Bronze Plating. (Advance sheets of paper to be presented at the Thirty-seventh General Meeting of the American Electrochemical Society, April 8–10.)—F. C. MATHERS and STANLEY SOWDER detail experiments to determine the practicability of depositing copper-tin alloys electrically, and find this possible under certain conditions. Bennett (*Trans. Amer. Elec.-chem. Soc.*, 1913, vol. xxiii, 255) collected data for all the bronze-plating baths so far described and found them practically all unsatisfactory. Commercially, bronze color is imitated with brass or coloring by a reagent. Some German investigators obtained satisfactory results for a time with a bath containing copper sulphate, sodium hydroxide, stannic chloride, and sodium tartrate, but it soon became useless.

Mathers and Sowder experimented with a bath constructed as follows: Two anodes (90 per cent. copper and 10 per cent. tin) 4 by 4 cm. were used in each bath, the content of which was 200 c.c. The single cathode in each was 4 by 4 cm., and the temperature 40° to 50° C., the current density 0.4 ampere per square decimeter. A decrease of current density caused increase of deposition of the more easily separated ingredient, which separability, however, differed with the composition of the bath, copper separating more readily from the oxalate bath and tin from the cyanide-stannate bath.

The following solutions were used:

Oxalates.—Ammonium oxalate, 5.5 per cent.; copper sulphate, 1.5 per cent.; stannous oxalate, 0.42 per cent.; oxalic acid, 0.5 per cent. gave a bronze deposit for a short time, but soon the only result was a hard brittle copper, due to poor corrosion of the anodes. As 5.5 per cent. ammonium oxalate will dissolve much more of the two metals than the quantity used at first, tests were made with more concentrated solutions, but satisfactory deposition was not obtained. After many experiments, the following method was found serviceable: A 500 c.c. bath containing 6 per cent. ammonium oxalate, 2 per cent. copper oxalate, 1.6 per cent.

ammonium citrate, 1.2 per cent. potassium sulphate, and 0.4 per cent. citric acid was electrolyzed with copper anodes. Fifty c.c. of the solution was removed and strips of pure tin inserted, whereby copper was precipitated and tin dissolved. Every few hours this treatment was repeated and the previous portion was filtered and returned to the bath. In this manner the ratio between the metals was kept fairly constant. One of these baths was maintained in efficient operation for two months.

Cyanides.—Good deposits were obtained from a bath containing potassium hydroxide, 5 per cent.; potassium cyanide, 0.2 per cent.; stannic ammonium chloride, 0.38 per cent.; and potassium copper cyanide, 1.5 per cent. The bronze anodes remained bright and free from slime, but for several days only copper was deposited, which action the authors believe to be due to the necessity for reduction of the stannic to the stannous condition. The use of much free cyanide decreases the rate of copper deposition and gives tin-colored coating. The current density and temperature used for the above bath were the same as those for the oxalate bath.

H. L.

Artificial Abrasives.—The manufacture of artificial abrasives —silicon carbide and corundum—in the electric furnace is described by C. J. BROCKBANK (*Journal of the Society of Chemical Industry, Transactions*, 1920, xxxix, 41–43). For silicon carbide or carborundum, electric furnaces with a capacity of 1000 to 3000 horsepower are used; the yield per unit of power is somewhat larger in the largest furnace, but the product is somewhat inferior in quantity to that made in the smallest furnace. The 1000 horsepower furnace has an inside width of 5 or 6 feet, and a length of 20 feet between the heads which carry the electrodes. These heads are 40 inches thick. Each terminal has two electrodes of graphite, 10 inches in diameter and 48 inches long. A resistor core of 1200 pounds of graphite powder is placed between the electrodes; it forms a layer 36 inches wide and 10 inches deep, and carries the current. The charge lies below, above, and on both sides of this core. A typical charge, using new materials, contains 1500 pounds petroleum coke, 2520 pounds white sand, 300 pounds sawdust, 40 pounds salt. The sawdust is used to make the mass porous, facilitate escape of the carbon monoxide formed in the reaction, and prevent formation of blowholes. The salt aids in the elimination, as chlorides, of impurities present in the sand and coke. The entire charge is not converted into carborundum; a portion merely serves as a heat-insulating blanket. This unused portion is added to the next charge which has the following composition: Petroleum coke, 1500 pounds; sand, 2455 pounds; sawdust, 300 pounds; old mixture, 400 pounds; salt, 40 pounds. The furnace is run at a voltage between 85 and 160, usually 85 and 100, for a

period of thirty-two to thirty-four hours. Each pound of crystalline carborundum produced requires 5 kilowatt-hours of electric energy. The crystalline product is removed from the furnace after cooling, is crushed, treated with sulphuric acid, and then with caustic soda to remove surface impurities, washed, dried, and screened. For abrasive wheels, it is mixed with a porcelain bond, and fired in a pottery kiln.

In the manufacture of artificial corundum (aluminum oxide) a typical furnace mixture is: Calcined bauxite ore, 1750 pounds; coke, 100 pounds; iron borings, 350 pounds. A layer of the mixture 1 foot thick is placed on the carbon hearth, a train of graphite powder is laid from electrode to electrode, and the furnace is started. As soon as a molten path is formed, it carries the current, and more charge is added. The usual voltage is 100; from 4 to 5 tons of corundum are produced in a furnace with the expenditure of 18,000 kilowatt-hours of energy. Reduction is not carried too far, for traces (1 to 2 per cent.) of the oxides of iron, silicon, and titanium increase the toughness of the product. The iron oxide and silica present in the charge are reduced to metal, alloy, and sink to the bottom of the furnace. The iron borings in the charge are used to keep the silicon content of this alloy below 15 per cent., and thereby facilitate its magnetic separation from the crushed carborundum.

J. S. H.

Steel in Tension, Compression and Shear. F. B. SEELY and W. J. PUTMAN. (*Bulletin No. 115 Engineering Experiment Station of the University of Illinois.*)—The severe uses to which carbon and alloy steels are put in some phases of engineering, as for example, in automobile and in aeroplane construction, have developed a need for more detailed knowledge of the action of steel, under various types of stress, as well as of the factors which affect the physical properties of the material.

Our knowledge of the breakdown of elastic action of ductile materials, particularly in the case of combined loading, is limited. The various theories of combined stress lead to results which differ rather widely when applied to various machine parts or to structural elements, such as thick cylinders, flat plates, crank shafts, webs of girders, etc. The maximum shear theory of combined stress for ductile materials as expressed by Guest's law, which has gained rather wide acceptance in recent years, assumes that the elastic shearing strength is one-half of the elastic tensile strength. Available experimental results, however, have, in general, failed to justify this assumption. The importance of the limitation imposed by the shearing stress upon the elastic strength of ductile material is, of course, generally recognized. It is of special importance to know the relation between the shearing and the tensile (and compressive) elastic strengths for various grades of ductile and semi-ductile steels. The

main object of the investigation herein recorded was to determine carefully the elastic shearing strength of ductile and semi-ductile steel and to find the ratio of the elastic shearing strength to the elastic tensile strength with the hope that definite information would thereby be obtained on the breakdown of the elastic action of various grades of steel and on the limits of the theories of combined stress.

Apart from the problem of combined stress there has been also a lack of knowledge of the correct elastic shearing strength of various grades of steel and of the general nature of elastic shearing failure as well as of methods of determining the correct shearing strength from tests.

This bulletin presents the results of experiments with six grades of steel, three carbon steels and three alloy steels; namely, soft, mild, and medium carbon steel; and vanadium, nickel, and chromic-nickel alloy steel. The elastic strength in tension, in compression, and in shear is given for each of the six grades of steel.

R.

Turbine Steels. W. H. HATFIELD and H. M. DUNCAN. (*North-East Coast Institution of Engineers and Shipbuilders,* March 19, 1920.)—This Paper constitutes a report of:

1. An investigation into the response which commercial forgings made to the different forms of mechanical testing now in vogue.

2. Similar investigations into the mechanical properties of turbine parts which had given satisfactory service and also of those which had failed, with a view to eliciting reliable information concerning the relative importance of the different values to be obtained from the different forms of mechanical tests.

3. Experiments with the four steels covered in the British Electrical and Allied Manufacturers' Association specification with a view to determining the mechanical properties, under laboratory conditions, of size, heat-treatment, etc.

4. Considerations in the light of the results obtained from items 1, 2 and 3, as to which, if any, additional forms of test might be adopted for inclusion in the British Electrical and Allied Manufacturers' Association specification.

The following mechanical tests, which are briefly described in the Paper, were employed during the investigations, and the results obtained are reported: tensile, torsion, bend, Charpy, Fremont and Izod tests; Arnold alternating test; Stanton, Sankey and Brinell tests; "Shore Scleroscope" hardness tests.

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